Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level

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Alain Franc, Olivier Laroussinie, Timo Karjalainen (eds.)

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Editorial Office: European Forest Institute
Torikatu 34
FIN-80100 Joensuu, Finland

Phone: +358 13 252 020
Fax. +358 13 124 393
Email: publications@efi.fi
WWW: http://www.efi.fi/

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Contents

	Preface	5
P. N. Duinker	Criteria and Indicators of Sustainable Forest Management in Canada: Progress and Problems in Integrating Science and Politics at the Local Level	7
C.C. Harris et al.	Rural Community Assessments Applying Criteria & Indicators for Sustainable Resource Management	29
I. Iorgulescu et al.	Field Testing Criteria and Indicators for Forest and Wood Workers in Ghana	45
P. Angelstam et al.	Toward the Assessment of Forest Biodiversity at the Scale of Forest Management Units – a European Landscape Perspective	59
T-B. Larsson	Biodiversity Evaluation Tools for European Forests	75
L. Eriksson, and A. Lindhagen,	A Model Indicating Effects of Multipurpose Use of Forestry on Stand Level	83
U. Nopp et al.	Parameters for the Assessment of the Predisposition of Spruce-Dominated Forests to Various Disturbing Factors with Special Regard to the 8-toothed Spruce Bark Beetle (Ips typographus L.)	99
R. Suchant and R. Baritz	A Species-Habitat-Model for the Improvement and Monitoring of Biodiversity in Modern Ecological Silviculture – Capercaillie (Tetrao urogallus) in the Black Forest	109
B. Finegan et al.	Timber Production and Plant Biodiversity Conservation in a Costa Rican Rain Forest: an Experimental Study and its Lessons for Adaptive Sustainability Assessment	123
J. Ghazoul	A Framework for Monitoring Indicators of Ecological Sustainability in Tropical Forestry	135
E. Bousson	Development of a Multicriteria Decision Support System Adapted to Multiple-Use Forest Management: Application to Forest Management at the Management Unit Level in Southern Belgium	151
B. Farthing et al.	Site Based Monitoring – How Many and How Long?	165
J-L. DesGranges et al.	The Use of Predictive Models of Breeding Bird Assemblages for Assessing and Monitoring Forest Bird Diversity	181

R. Gagnon Is Imitating Nature the Solution for Sustainable Boreal Forest (Black Spruce) Management in Eastern Canada? 201

D. Auclair et al. Landscape Visualisation Software as a Forest Management Decision Support System 207

T. Mrosek and D. Balsillie Development and Testing of a Criteria and Indicators System for Sustainable Forest Management at the Forest Management Unit Level: Case Study at the Haliburton Forest & Wild Life Reserve Ltd., Ontario, Canada. 215

T. E. Howard Implicit and Explicit Paradoxes in Managing Certified Forests in the United States 237

A. Boncina Concept of Sustainable Forest Management Evaluation in the Forestry Planning at the Forest Management Unit Level: Some Experiences, Problems and Suggestions from Slovenian Forestry 247

Preface

These proceedings present to a wider audience the papers presented at a conference organized by GIP Ecofor and EFI on behalf of IUFRO Task Force on Sustainable Forest Management, and under the auspices of FAO, CIFOR and CATIE, at Nancy, 22–25 March 2000.

The paradox with sustainable forest management is that, on the one hand, it seems very appealing, challenging and new for some groups, and on the other hand, very classical and already implemented in management plans, for other groups. This issue has not been resolved during the congress, but some elements can be put forward to shed some light on it. Foresters are probably faced with an important shift in paradigm: one facet of the paradox refers to the notion of sustainable yield, and the other to sustainable forest management.

The former is a more restricted concept than the latter. Most silvicultural rules rely explicitly on long-term sustainability of forest cover, and implicitly on the assumption that sustainability of yield and forest cover guarantees sustainability of all functions, goods and benefits of the forest. Such an automaticity is no longer true. For example, it should not be taken for granted that sustainability of the tree cover guarantees the sustainability of the soil fauna and flora. Some means of assessing the sustainability of the other functions, goods and benefits needs to be developed. Criteria and Indicators are the tools, which enable such an assessment.

A second element of the paradox is the extraordinary diversification of the functions, goods and benefits produced by forests, and the tremendous deepening of scientific knowledge on the functioning of forests and the key role that diversity has for the sustainability of some functions.

A third element that feeds the paradox is the increasing diversity of stakeholders involved in forest planning and management. The need for regulating the exchanges between stakeholders, and the access to forest resources, has never been as acute as it is today. The diversity of stakeholders increases the possibilities of conflicts, and the difficulty to reach a consensus on how to design and implement a management or a conservation plan.

Most of the forest values have been allocated classically into a three-fold framework:

- Productive values: wood quantity and quality, forested areas, etc.;
- Biological values: conservation of local flora and fauna; and
- Social benefits: recreation, suburban forests, etc.;

Recently, some new values have emerged as equally important to the values given above:

- Extension of productive values to non wood products;
- Preservation of ecological functions at a landscape level, such as hydrological cycles, biochemical cycles, etc.;
- Preservation of ecological functions at a global level, such as carbon sequestration;
- Preservation of biological diversity; and
- Preservation of cultural and spiritual values;

Alain Franc, Olivier Laroussinie and Timo Karjalainen (eds.)
Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level
EFI Proceedings No. 38, 2001

The possibility to develop consensus on C&I for such a variety of C&I is challenging. Therefore, there is an appeal for simplification, with biodiversity acting as a surrogate for sustainability, in the same way that yield and forest cover have played such a role until the 1970s. However, there is no scientific information for, or against, this proposal. For this reason, a session has been specifically dedicated to biodiversity.

One obvious difficulty is that the values are assessed at different scales: the forest management unit (FMU), the landscape, the ecoregion, and even the global scale. Assessing C&I at the FMU level can be an example of the motto 'think globally, act locally'. It should be kept in mind that such a scaling is far from being either obvious or even relying on a firm and steady scientific basis. This is an immense, complex area where suitable research is urgently needed. It is one objective of the IUFRO Task Force to share experience between stakeholder and scientists to evaluate the feasibility of such a programme. Whereas C&I have been developed through negotiation at national levels in processes such as the Pan-European process, such a debate has not fully percolated downwards to the stand or FMU level. For this reason, a challenging question addressed in the last session has been to contribute to the assessment of sustainability at stand or FMU level.

A second difficulty is that the lack of consensus on C&I is reflected in a lack of consensus in vocabulary. However, in order to negotiate, the issue of sharing a common vocabulary is crucial. This process is probably an ongoing cooperative process, with stability and harmonization of vocabulary reflecting progressive consensus on estimation of sustainability of values by C&I. It is noteworthy that the level of reachable harmonisation is variable: principles are accepted as intangible, whereas indicators are most commonly adapted locally. The situation of criteria is more balanced: criteria are becoming harmonized at national levels, and such harmonization is still questionable for criteria at the local level.

C&I are a key part of the implementation of forest management. They are the tool which enables societies and stakeholders to reach a consensus – partly on a scientific basis, and partly through political negotiation – on the crucial questions: how and why to manage or to conserve our forests?

Finally, having all this information in mind, the programme of this conference has been organized as follows:

Session I: Economic, social and participation issues in SFM;
Session II: Biodiversity issues in SFM;
Session III: Modelling and quantitative approaches for assessing sustainability or diversity;
Session IV: Assessment of C&I for SFM at the stand level.

The papers are presented in the remainder of the book following the order they were presented in these sessions. The first paper is the invited keynote paper by Peter Duinker, who presents a comprehensive and global survey of a multi-disciplinary approach for implementing C&I for sustainable forest management in management practices.

Last, but not least, we would like to thank Dominique Danguy des Deserts, Head of Engref at Nancy, our host city, who contributed so much to the organization and the comfort of this meeting, and Tim Green, from EFI, whose constant efforts and angel patience during the whole multi-disciplinary review process enabled these proceedings to be published.

Alain Franc, Inra, Paris, France
Olivier Laroussinie, Ecofor, Paris, France

Criteria and Indicators of Sustainable Forest Management in Canada: Progress and Problems in Integrating Science and Politics at the Local Level

Peter N. Duinker

School for Resource and Environmental Studies
Dalhousie University
Halifax, Nova Scotia, Canada

Abstract

The paper begins with a discussion on the background and context for criteria and indicators of sustainable forest management (C&I-SFM), along with some definitions and concepts and a review of the history of C&I-SFM in Canada. It highlights the importance of paying careful attention to both scientific and socio-political dimensions in any exercise of developing and using C&I-SFM at any scale. Science provides the protocols for reducing uncertainty, and politics provides protocols for channelling people's behaviour. C&I-SFM are at risk of being neither defensible nor useful if the scientific and political bases are weak. The main focus is a series of problems and pitfalls associated with indicator development and application. Many chosen indicators fail to measure up to the qualities one must expect of them for defensibility and usefulness. The paper concludes with a short example of the use of biodiversity indicators in management planning for a publicly-owned industrial forest in central Alberta. Both mistakes (and their associated lessons) and successes are identified. The conclusion offers some key ways by which we must continue making progress with C&I-SFM.

Keywords: Criteria and Indicators, sustainable forest management, Canada, Alberta

1. Introduction

1.1 Background

Sustainability has become the key focus of forest management across Canada in the 1990s. Indeed, this is the situation around the world too. Numerous commissions, panels,

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EFI Proceedings No. 38, 2001

roundtables, and working groups – at local, regional, national, continental and global levels – have recently addressed the topic of forests and sustainable development, all of which have called on foresters at all levels to achieve sustainability of one sort or another.

Concepts of sustainability related to forests are gathered under several synonymous banners. In addition to 'forest sustainability' (e.g. OFPP 1993; Legislative Assembly of Ontario 1994), the most common of these are: 'sustainable forest development' (e.g. Standing Committee on Forestry and Fisheries 1990); 'sustainable forestry' (e.g. Aplet et al. 1993; Maser 1994); and 'sustainable forest management' (e.g. CCFM 1995; CSA 1996). Depending on which document one might be examining at any moment, the things to be sustained range from timber harvests in the timber-based industry (e.g. Forest Industry Action Group Steering Committee 1993), through non-timber forest uses, through forest ecosystems, to forest-based communities (e.g. OFPP 1993).

One trait is common to most discussions and analyses of sustainability – how should progress be gauged? There is no argument about whether there is a need to measure progress – that is clear and unchallenged. The question that remains, though, is how. Soon we should have some solid guidance on this question; huge efforts are being made around the world to try to measure progress toward sustainability. In the meantime, I still sense a great deal of confusion and disagreement on various themes related to measuring progress, a situation that permeates all groups within the forest sector, including governments, forest-products companies, non-government organizations (NGOs), consultants, and academics.

In this paper, I will lay out my thinking on the whole topic of criteria and indicators (C&I) of sustainable forest management (SFM), with a focus on the local level. I begin with a discussion on concepts and definitions, and then give a brief overview of C&I-SFM developments in Canada. Then I will highlight the relative roles of science and politics in the whole sustainability game, and follow that with some thoughts, first on progress with sustainability measurement, and then on pitfalls. While progress has been substantial, I presume it to be already well described in the literature. On the other hand, I believe that the pitfalls currently require more attention. Before concluding, I describe the sustainability measurement dimensions of my forest biodiversity assessment research project in Alberta.

1.2 Definitions and concepts

1.2.1 Main terms

Criterion – In the Canadian context, a 'criterion' is a large component (or cluster of values) of the overall forest system, interpreted broadly as including forest ecosystems, forest management systems, and forest policy systems (CFS 1995). According to The Montreal Process (1995, p.5), a criterion is "a category of conditions or processes by which sustainable forest management may be assessed." The Canadian Standards Association (CSA 1996, p.3) defined a criterion as "a distinguishable characteristic of SFM; a value that must be considered in setting objectives and in assessing performance." These definitions are largely consistent with each other. An example, to use the words of the Canadian Council of Forest Ministers (CCFM 1995; 1997) is 'Conservation of Biological Diversity'.

Unfortunately, this conception of criterion is inconsistent with the common conception used in evaluation for decision-making (where, according to my understanding, a criterion specifies a condition or level for a specific value or indicator against which satisfaction is gauged). However, it seems now to have been accepted in the Canadian forest community, and indeed much beyond although not everywhere. 'Criterion' according to the Forest Stewardship Council (FSC 1996) is a second-order statement (second to the concept of

‘principle’) specifying behaviour and conduct. This is consistent with the view of Prabhu et al. (1999, p.86) that a criterion is “a principle or standard that a thing is judged by.” They go further and state that “a criterion can, therefore, be seen as a ‘second order’ principle” (Prabhu et al. 1999, p.86). Whenever I use the term ‘criterion’ in the context of C&I, I mean it in the first sense above (i.e. a category), and whenever I use it in the context of principles and criteria, I mean it in the second sense above (i.e. a second-order principle).

Indicator – Again in the Canadian context, an ‘indicator’ is a measurable attribute of a system component (CFS 1995). The Montreal Process (1995, p.5) defined indicator as “a measure (measurement) of an aspect of the criterion.” An indicator is “a measurable variable used to report progress toward the achievement of a goal” according to the CSA (1996, p.3). Prabhu et al. (1999, p.87) defined an indicator as “any variable or component of the forest ecosystem or management system used to infer the status of a particular criterion.”

Even when people adopt one of the definitions above and then try to identify indicators, they frequently end up with a wildly mixed bag of entities called indicators. For example, in the first state-of-the-forest report for the Eastern Ontario Model Forest (Johnson and Heaven 1999), one of the indicators is labelled ‘percent and area of forested land’, another is called ‘climate trends’, and yet another is called ‘mutual learning mechanisms’. The first fits the definitions above rather well, but the last two can hardly be called indicators as measures.

A key problem in determining whether something in a C&I exercise is an indicator is the sheer complexity of the array of concepts to be accounted for. This complexity problem is invariably tackled using a hierarchy of concepts. In Canadian parlance, we use the term ‘element’ to denote categories that together comprise or describe a criterion. Thus, conservation of biological diversity (biodiversity, for short) gets divided into ecosystem diversity, species diversity, and genetic diversity. Unfortunately, we try to identify indicators directly for each element, and in many cases this is impractical. For example, in the CCFM (1995) C&I, the following indicators are proposed for the element called ‘ecosystem diversity’:

1.1.1 Percent and extent, in area, of forest types relative to total forest area;
1.1.2 Percent and extent of area by forest type and age class;
1.1.3 Area, percent, and representativeness of forest types in protected areas;
1.1.4 Level of fragmentation and connectedness of forest ecosystem components.

The first three statements above are indicators, but the fourth is not. It is still a concept for which we may identify indicators. Two example indicators for forest fragmentation might be: (a) proportion of forest area designated as ‘core’ habitat; and (b) contrast-weighted edge density. In summary, I use two main tests for determining whether something is an indicator: (a) is it void of any specification of the desired level of the entity being measured (if the level is there, then the entity statement includes more than an indicator, as discussed below); and (b) is it possible to specify directly the appropriate units of measure (if not, then further specification of the entity is required).

Sustainable Forest Management – I am happy to rely on the definition provided by the CSA (1996, p. 4), which itself relied on the goal in the first Canada Forest Accord (CCFM 1992a): “SFM is management to maintain and enhance the long-term health of forest ecosystems, while providing ecological, economic, social and cultural opportunities for the benefit of present and future generations.”

1.2.2 Additional terms

Having been bothered by the terminological confusion around C&I-SFM and their applications in forest decision-making, I created my own set of definitions and relationships

for use in teaching, research and planning exercises. I did this partly to sort out some confusing relationships among concepts as presented by the CSA (1996). Here are definitions and examples for the concepts of value, goal, indicator and objective:

Value – things for which someone would deem a forest important, e.g.:
- process (e.g. carbon sequestration, water quantity regulation, recreation);
- physical entity (e.g. timber, moose, marten pelts);
- forest condition (e.g. biodiversity, soil bulk density).

In this context, a criterion is a sort of 'mega-value' or large grouping of values.

Goal – a directional statement for a value (need not be stated in quantitative terms), e.g.:
- have forests become long-term net sinks of atmospheric carbon;
- produce a continuous non-declining flow of quality wood to meet mill needs;
- maintain current levels and types of biodiversity.

Indicator – a measurable variable (quantitative or qualitative) relating directly to one or more values, e.g.:
- for carbon sequestration, kg/ha/yr net carbon flux;
- for timber, m3/yr harvest volume;
- for biodiversity, age-class structure of the forest.

Objective – a directional statement for an indicator (must be stated in objective terms), e.g.:
- more than zero kg/ha/yr (i.e., a positive number) for net carbon intake;
- at least 500 000 m3/yr of softwood pulp;
- 10% or more of total forest area in each of five development stages at any time.

As shown in Figure 1, there are strict relationships among the four concepts. Thus, for each value, there is a goal statement and one or more indicators. For each indicator, there is one objective statement. The value is 'satisfied' if the goal is reached. The goal is reached if all the objectives are reached.

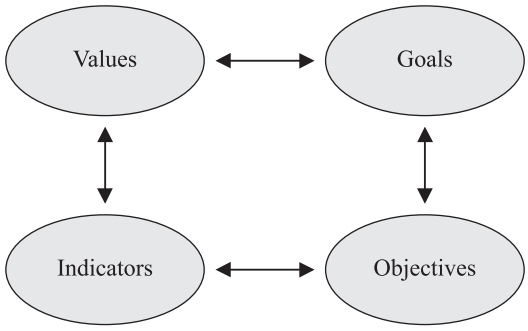

Figure 1. Relationships among value, goal, indicator and objective.

2. History of C&I-SFM Developments in Canada

Two parallel developments gave rise to a late 1990s groundswell of activity in Canada aimed at developing, testing and applying C&I-SFM. One was the emergence during the 1980s of sustainable development as a guiding concept for all of society's major pursuits. The other

was the search for effective and efficient ways of measuring performance in human activities. The two parallel developments converged in the late 1980s and early 1990s under the general mantle of sustainability indicators. Here I summarize these two developments, and then briefly mention the main 1990s Canadian C&I-SFM initiatives of which I am aware. These latter represent the sectoral manifestation of the general focus on sustainability indicators.

2.1 Forests and sustainable development

Canadians embraced the sustainable-development concept wholeheartedly from an early stage. A National Task Force on Environment and Economy (1987) was set up in 1986. This was at the same time that the World Commission on Environment and Development (WCED 1987) was trotting around the globe doing consultations. The Canadian Environmental Advisory Council (CEAC 1987) reviewed the WCED (1987) report, and made recommendations to the Minister of Environment. In 1988, the Task Force gave way to the National Round Table on Environment and Economy (NRTEE), a body that is still active today.

The forest community was quick to latch onto sustainable development as the central concept underlying progress in both management and policy. Regarding initiatives pertaining to forests and sustainability, the following deserve mention:

a) The Canadian Council of Forest Ministers (CCFM 1990) convened a National Forum on Forests and Sustainable Development in 1990.
b) NRTEE set up a Forest Round Table on Sustainable Development in 1991 (Thompson and Webb 1994).
c) The Canada Department of Forestry Act (House of Commons of Canada 1989) was a landmark piece of legislation (since repealed) in the sense that it led the pack of forest legislation developments addressing sustainability. The Act called on the Minister to have regard for the sustainable development of Canada's forests.
d) Canada is now in the habit of establishing a so-called national forest strategy every five years. Each strategy represents a sort of consensus-based statement on how to improve forests and forestry in Canada. The 1992 and 1998 strategies, entitled "Sustainable Forests: A Canadian Commitment" (CCFM 1992b; 1998), contain roughly a hundred action items that are expected to lead the Canadian forest sector in a sustainable direction.
e) The Canadian Model Forest Program was initiated in 1992 as a major endeavour to research and demonstrate how to implement SFM in various regions across Canada (CFS 1999a). The model forests, of which there are currently eleven plus an adjunct, are organizations and landbases where 'best' SFM practices are being developed, tested, documented and shared. A key feature of each model forest is the partnership of organizations and individuals which strives for consensus on how to manage the forest for the myriad values brought to the table by the partners.
f) Under the auspices of the Canadian Council of Forest Ministers and led by the Canadian Forest Service, a national effort has developed a set of C&I-SFM for Canada (CCFM 1995). This work was underway in concert with several international initiatives in which Canada has (or at least Canadians have) played a significant role, including UNCED and the Montreal Process and Santiago Declaration (The Montreal Process 1995).
g) Many of Canada's provinces launched SFM initiatives in the late 1980s and early 1990s. For example, the Government of Ontario established a Sustainable Forestry Initiative in 1991, with a wide range of activities including a high-level inquiry into securing forest sustainability through policy reform (OFPP 1993) that led to a Policy Framework for Sustainable Forests (OMNR 1994). Coupled with the world's largest-ever EIA on forest management (Koven and

Martel 1994), the policy framework provided the conceptual basis for replacement of the Crown Timber Act by the Crown Forest Sustainability Act in 1994 (Legislative Assembly of Ontario 1994). Other provinces have similarly been entrenching sustainability into their policies, statutes, regulations and guidelines for management of provincially-owned public forests, which we must remember constitute over 70% of Canada's entire forest area, and a much higher proportion of the commercial timber landbase.

2.2 Indicators of sustainability

In my view, the forerunner to sustainability thinking as we know it in the 1980s and 1990s was the great concern for environmental impacts of economic development that arose through the 1960s and 1970s. This concern led to environmental protection legislation, setting up of environment departments in governments, industries, consulting firms and universities, establishment of powerful environmental NGOs, and public-scrutiny processes like environmental impact assessment (EIA). EIA became the main mechanism whereby private-sector and regulatory decision-makers, and indeed the public, would evaluate the environmental, social and economic performance of major development decisions. From EIA's beginning in the early 1970s to the current day, we have struggled with the problem of deciding in what terms we will measure environmental impacts (e.g. Beanlands and Duinker 1984).

Hot on the heels of sustainable development thinking in the late 1980s came a rash of attention to sustainability indicators, especially in the context of ecological monitoring and state-of-the-environment reporting. Examples of such work include a host of national workshops and reports on ecological monitoring for and indicators of the state of the environment (e.g. Stokes and Piekarz 1987; Environment Canada 1992) and on indicators of ecologically sustainable development (e.g. Potvin 1991; Ruitenbeek 1991; Victor et al. 1991). Various other reports have been published by research institutes (e.g. Hardi and Pinter 1994) and government departments (e.g. Hardi et al. 1997). Canada's Department of Environment worked through the 1990s on a series of national environmental indicators, issuing periodic bulletins highlighting results for specific indicators including some for the forest sector (e.g. Environment Canada 1995). Canada's Commissioner of the Environment and Sustainable Development (1998) is also tackling the issue of performance measurement for sustainable development. Given the relevance of state-of-the-environment reporting at provincial and local levels as well, governments at these levels have also been active in developing and applying indicators (e.g. Alberta Round Table on Environment and Economy Secretariat 1994; Planning and Development Department, Regional Municipality of Waterloo 1991).

2.3 C&I-SFM

2.3.1 Canada's national initiative

Forest-sector people in Canada were explicitly concerned about how to measure performance in SFM at least from the late 1980s. What galvanized attention on C&I-SFM and got the ball rolling may have been the commitment made in the 1992 National Forest Strategy (CCFM 1992b, p.25) that "by 1993, the federal government will develop a system of national indicators to measure and report regularly on progress in achieving sustainable forest management". While the federal government did not meet this deadline, the process was put into full swing shortly after a high-level seminar of experts was convened in Montreal in 1993 on the topic of "Sustainable Development of Boreal and Temperate Forests" (CFS 1994a).

The process for developing Canada's national C&I-SFM, under the auspices of the CCFM, was led by a Working Group with secretariat provided by the Canadian Forest Service (Riley 1995). The Working Group used a consultative process, involving the typical broad array of academics, industrial personnel, government people, and interest-group representatives, to get agreement on: (a) key components of the forest system (criteria); (b) key measurable attributes of the components (indicators); and (c) ways to collect data about the attributes (monitoring systems).

The six criteria agreed on in the Canadian process, much in line with the criteria of the Montreal Process (1995), include the following (with my paraphrasing and annotations):

1. biodiversity (variability among living organisms from all sources and the ecological complexes of which they are part);
2. forest ecosystem condition and productivity (health, vitality and rates of biotic production);
3. soil and water (maintenance of soil and water quantity and quality);
4. forest ecosystems and global ecological cycles (contributions of forests and forest activities to global ecosystem functions);
5. multiple benefits to society (flows of forest benefits for current and future generations); and
6. society's responsibility for sustainable development (fair, equitable and effective forest management choices) (CCFM 1995).

The CCFM (1997) has reported once already against as many of the CCFM (1995) indicators as possible, but from the beginning of Canada's annual state-of-the-forest reporting, the documents (Forestry Canada 1991, 1992, 1993; CFS 1994b, 1995, 1996, 1997, 1998, 1999b) have included data on a variety of environmental, social and economic indicators related to SFM.

2.3.2 Canada's model forests

C&I-SFM have been a central theme for Canada's model forests during Phase II (1997–2002) of the program. Overall, a huge and positive effort has been expended, with numerous reports documenting the progress (CFS 2000a; 2000b).

2.3.3 The Canadian Standards Association SFM System Standard

Late in 1993, representatives of the Canadian forest-products industry requested the Canadian Standards Association (CSA) to undertake development of a standard for a sustainable forest management (SFM) system. Using a consultative, consensus-seeking process, the CSA developed the required standard (CSA 1996) to be consistent with the ISO 14 000 standard series on environmental management systems. The standard is voluntary, and focuses on the following four components: commitment; public participation; management system; and continuous improvement. The management system has five elements: preparation; planning; implementation; measurement/assessment; and review/improvement.

SFM, as defined by the CSA standard (CSA 1996), fundamentally requires forecasting and monitoring of a broad suite of indicators chosen to represent the status of selected values represented by 21 elements that link directly to the set of nationally accepted criteria (CCFM 1995). Parties registered to the standard must consider the national indicators as they develop local indicators, and must end up with at least one indicator for each element (CSA 1996).

The CSA SFM System Standard is one of the three main schemes in Canada for 'certifying' sustainable forest management. The other two schemes are those of the Forest Stewardship

Council (truly a certification mechanism complete with an ecolabel) and the ISO 14 000-series environmental management system. At the time of writing, Canadian industrial forest managers and owners are favouring ISO over the FSC and CSA, but there are two industrial forests now registered to the CSA standard. As more forests are CSA-registered, the concept of formal C&I-SFM will grow.

2.3.4 Other initiatives

Many other initiatives are underway across Canada to promote, develop, test and implement C&I-SFM. Apart from a variety of model-forest ventures, I have been personally involved in three such initiatives. All were designed, in part, to analyse a large suite of suggested indicators and make judgements on their technical soundness for the purposes of indicating progress in SFM. For Ontario's Forest Ecosystem Science Cooperative in one project (Wedeles et al. 1998) and for the Great Lakes Forest Alliance in another (Williams et al. 1998), we first created a set of ideal indicator characteristics, and then subjected the indicators to an analysis of how well the indicators measured up to ideal expectations. We were surprised at how many proposed indicators could not withstand a strong technical scrutiny. In the final project, one of my graduate students has evaluated a suite of indicators proposed for use in judging the sustainability of resource-based remote tourism in the forest interior of Northern Ontario (Johnson 2000). Her work points out that forest-ecosystem sustainability is a key element in sustaining the tourism industry.

3. Why Both Science and Politics Are Important in C&I-SFM

The paper has the sub-title "Progress and Problems in Integrating Science and Politics at the Local Level" because I firmly believe that both science and politics have vital roles to play in making good progress with C&I-SFM. My beacon here is the influential book by Lee (1993) entitled "Compass and Gyroscope: Integrating Science and Politics for the Environment". Lee advocated the science of adaptive management (e.g. Holling 1978; Walters 1986) as the compass. Adaptive management helps us reduce critical uncertainties regarding the long-term social, economic and ecological consequences of our development decisions. Lee (1993) further advocated the politics of bounded negotiation (e.g. Fisher et al. 1991) as the gyroscope. Negotiation provides an avenue for channelling people's behaviours and energies in positive ways to find resolutions to their conflicts.

Working with C&I-SFM is both scientific and political business. No one denies the scientific part – determining objective and valid ways to measure the state of things important to people, designing statistically valid data-collection protocols, using explicit models to make indicator forecasts, and so on. But science in the sense of sustainability is demanding in at least two ways. In one, people making assessments of sustainability are called to implement the basic tenets of adaptive management in a rigorous way (e.g. CSA 1996). This means rigorous indicator forecasting, rigorous indicator measurement over time, and rigorous comparison of forecasts with measurements to yield fundamental learning and reduction of uncertainty (Duinker and Baskerville 1986; Duinker 1989). In another, we are sobered with the thoughts that the kinds of science we have become accustomed to practising need adjustment when applied to long-term sustainability of broad-scale social/economic/political/ecological systems (Funtowicz et al. 1998), and that the boundaries between science and politics also need adjustment (Nowotny 1992).

However, politics, in the sense of participation and power and their influences on outcomes, also plays a significant role. There are at least three ways to look at that role. One concerns the politics of classification, an unavoidable activity in sustainability assessment. According to Bowker and Star (1999), any significant classification or categorization exercise involving multiple parties is an intensely political exercise. Their main example is the International Classification of Diseases, and we may expect that C&I-SFM might have far less trying politics in their development, but politics none the less.

For example, in the development of Canada's national set of C&I-SFM, how did it turn out that four of the six criteria were ecological (i.e. biodiversity, ecosystem productivity, soil and water, and global cycles)? One might have thought that sensibility would grant roughly equal attention to the three acknowledged pillars of sustainable development – the social, economic and ecological pillars. However, ecology fetched fully two-thirds of the attention. One might justify this outcome on the premise that ecological foundations must underpin economic and social activity, and not vice-versa. However, I would sooner believe that the prevailing moods of the day, plus the personal and professional orientations of the participants in the C&I-SFM design process, were much larger factors. If the group of people working on C&I-SFM is dominated by 'traditional' foresters, then the outcome is guaranteed to be weighted toward ecological concerns, with a minor emphasis on timber-related economics.

A second element of politics in C&I-SFM work is the need to have 'something for everyone'. This need is most notable in the setting of Canada's model forests. The model forests are partnership-based institutions where dozens of organizational representatives come together on an equal footing to try to reach consensus on a variety of SFM issues. All partners are invited to be part of all discussions and initiatives, especially in the C&I-SFM activities. Each person at the table has his/her own conception of what SFM means, and views on what needs to be tracked to give a good accounting of SFM progress. In the spirit of inclusiveness and maintaining good relations among partners, it may be necessary to include certain proposed indicators in a suite to be tested and applied even though those indicators have a weak scientific basis and can hardly help any of the partners determine favourable courses of action in the pursuit of SFM.

Finally, a third element of politics has to do with revealing the potential dark sides of performance. In making choices about what to include in C&I-SFM, it is tempting to suppress the use of indicators that could potentially show bad performance or that might unnecessarily raise public anxiety about forest management. On the other hand, one would focus on indicators that cannot but show positive performance and have the potential to calm public fears that forest management is out of control and forests are being degraded. It is only human to want to show our good side and hide the other.

There are doubtless more dimensions of politics in C&I-SFM work. My point is that efforts to work with C&I-SFM are inherently both scientific and political, and careful process design and implementation are needed to ensure that science and politics support each other, rather than work independently, or in an even worse case, work at odds with each other. Continued progress with C&I-SFM desperately needs a fruitful combination of the science of adaptive management and the politics of bounded negotiation.

4. Signs of Progress

Discussions in the previous sections make it clear that in Canada huge amounts of work have been done on sustainability indicators in general, and C&I-SFM in particular. One might question both the efficiency and effectiveness of the progress, and I will, but nevertheless it is progress. Compared with, say, ten years ago, I believe that people interested in Canada's

forests – nationally, provincially, locally – have access to much better and more information today, largely because of C&I-SFM initiatives and the associated reporting mechanisms.

For the purposes of this paper, I will be brief. Implementation of local-level C&I-SFM in Canada is well under way. Progress across the nation is uneven, with some excellent performances, and some lesser ones. We still have much progress to make before we can, if ever, settle into a routine of predicting, measuring and reporting on a tight set of indicators that will help all interested people come to reasoned judgements about progress in pursuit of sustainability. For my part, I may criticize developments on the technical (scientific) level, but politically the developments have been overwhelmingly positive. C&I-SFM, like certification and other mechanisms for fostering SFM, are serving as one of several umbrellas under which very fruitful discussions are taking place among forest stakeholders about the issues and problems that continue to plague the pursuit of sustainability. On one hand, the C&I-SFM process invites all stakeholders to participate, and on the other hand, it systematizes and disciplines the discussions so as to reduce the confusion brought on by emotionally driven discourse, and sheds reasoned light on what the problems really are and how they should be dealt with.

And it is a good thing that such progress is being made. In concert with the conception of SFM embodied in the CSA (1996) SFM Standard, I believe that C&I-SFM are necessary components (although insufficient) of SFM (Duinker 1997).

5. Signs of Problems and Pitfalls

5.1 Introduction

I have a considerable amount to say about the problems and pitfalls I see people encountering in their C&I-SFM work. The problems and pitfalls are described here in four sets, and they are all indicative of a lack of discipline in: (a) identifying and naming indicators; (b) classifying indicators; (c) evaluating indicator quality; and (d) applying indicators in the sense of generating useful data. I examine each in turn.

5.2 Identifying and naming indicators

In any indicator list, as mentioned above, I search for consistency in the language used to identify and name indicators. That consistency is gauged in two ways: (a) lack of reference in the name to a desirable (or any) direction for the indicator; and (b) specificity such that one can directly identify one or more appropriate units of measure. Examples are presented where insufficient work has been done to name indicators. The examples are drawn from a variety of Canadian reports, most of which are cited elsewhere in this paper.

- ‘Climate trends’ – this indicator suffers from both problems above. Thus, there is no need to mention ‘trends’ in the name, nor is climate sufficiently specific to move directly to units of measure. Climate is a broad concept, and is itself indicated by temperature, precipitation, and other well-known variables.
- ‘Mutual learning mechanisms and processes’ – after figuring out how to define such mechanisms and processes, the main challenge is to determine how to measure them. The units of measure are far from obvious.

- ‘Changes in distribution and abundance of aquatic fauna’ – there is no need to use the word ‘changes’ here. Changes are defined by differences over time. I am sure that the authors of this indicator were not adamant that the differences themselves are the indicator.
- ‘Trends in global market share’ – not only do we not need ‘trends’ in the indicator name, but the meaning of ‘global market share’ is elusive and demands much greater specification before becoming useful as an indicator.

I could go on, because the indicator literature is rife with such a lack of discipline. My point is made by now, though – we must exercise incisive thinking in the naming of indicators.

5.3 Classifying indicators

Here I am not referring to how indicators fit into a hierarchical scheme including criteria at the top, elements and sub-elements in the middle, and indicators at the bottom. Such hierarchies are necessary and pose their own challenges in making them useful organizational devices, but I am referring here to types of indicators. Most C&I-SFM sets do not partition indicators according to their function, as if they all had the same function or that function did not matter. I have encountered a few classifications of types of indicators in the literature. For example, according to Canada’s Commissioner of the Environment and Sustainable Development (1998), there are three types of indicators: (a) operational indicators, which measure potential stresses on the environment; (b) management indicators, which measure the results of management actions aimed at reducing stresses; and (c) state-of-the-environment indicators, which measure the condition or response of specific components of the environment.

I believe it is paramount to sort indicators into such categories so people can have a better understanding of what kind of phenomenon they are measuring with any particular indicator. I prefer a categorization and labelling as follows:

a) *Context indicators* – these are indicators about phenomena to which local management may react, but which cannot be influenced solely from the local level. Examples might be: (i) the exchange rate of the Canadian dollar, which has a strong effect on the financial viability of wood-based enterprises, but which those enterprises cannot change; and (ii) global climate change, to which all Canadian forest managers will have to react during the next century, but which they will not be able to influence measurably, no matter how much carbon their forests are managed to sequester.
b) *Action indicators* – these are indicators that measure the quantity and quality of actions taken in forest management. Examples might be: (i) number of trees planted, or hectares of pre-commercial thinning, and (ii) number of public meetings held.
c) *Condition/Response indicators* – these are indicators that measure how the forest system (broadly interpreted) responds to actions taken. Examples are: (i) population levels of forest-dwelling species; (ii) rates of net carbon flux to/from forest ecosystems; and (iii) number of sustainable recreational opportunities in a specific forest.

In practice, how one classifies a particular indicator in this framework may depend on the specific interpretation of the issue that prompts the indicator’s use. For example, one might see forest-based employment as a context indicator, an action indicator, or a condition indicator, depending on the specific situation and one’s point of view (personal communication, Martin von Mirbach 2000). Perhaps the greatest strength of such a classification is its ability to help people communicate to each other their various interpretations of a particular issue.

In my view, a strong state-of-the-forest report would present data on all three types of indicators (context, action, and condition/response) for any major forest-management issue, and would attempt to link them into functional groups to show cause-effect relationships. For example, if stresses to forests from the atmosphere constitute such an issue, then the indicator suite might include the following:

a) context indicators – temperature, precipitation, storm events, pollution deposition/event rates;
b) action indicators – rates and types of silvicultural treatments designed to enhance individual tree vigour; and
c) condition/response indicators – stand condition index, tree mortality rates, net primary productivity, mean annual increment, presence of indicator species (e.g. lichens).

The key here is that forest-management problems can hardly be solved, or even addressed, when a fragmented approach to indicators is taken. Good forest-management problem-solving would identify and link indicators from all three types in incisive systems analysis. Trying to understand SFM thoroughly without such systems analysis is a doomed exercise. Presenting indicators in a fragmented way, or presenting only one type for any particular forest-management issue, may provide interesting glimpses, but it is insufficient for charting and taking promising courses toward SFM.

5.4 Evaluating indicator quality

Sometimes forest-sector people engage in a C&I-SFM exercise without seriously examining whether the indicators have the kinds of characteristics we might expect of a good indicator. Having been personally involved in creation of the national set of C&I-SFM in Canada (CCFM 1995), I know this was not done in that exercise. Sets of such characteristics have appeared in the Canadian literature (e.g. CSA 1996; Wedeles et al. 1998; Williams et al. 1998; Johnson 2000). In a recent project (Duinker and Saunders 2000), the following set of indicator qualities were used to assess the overall utility of indicators used in the state-of-the-forest report for the Eastern Ontario Model Forest (Johnson and Heaven 1999). Examples are drawn from Canada's national set of C&I-SFM (CCFM 1995).

- *Relevance* – each indicator must relate clearly to a particular SFM criterion, and should represent significant information about the values embodied by the criterion (Wedeles et al. 1998; Johnson 2000). An example of a highly relevant indicator is 'forest age-class structure' in relation to biodiversity (criterion 1). An example of an irrelevant indicator is 'existence of laws and regulations on forest land management' in relation to global cycles (criterion 4).
- *Practicality* – to be effective, an indicator should rely on available or easily obtainable data (Wedeles and Williams 1999; Johnson 2000). It follows that the monetary cost of obtaining indicator data must not be unreasonable (CSA 1996; Wedeles and Williams 1999; Johnson 2000). An example of a highly practical indicator is 'habitat quality and quantity for selected species' in relation to biodiversity. An example of a much less practical indicator is 'total expenditures by individuals on activities related to non-timber use' in relation to societal benefits (criterion 5).
- *Sensitivity* – an indicator must be sensitive and responsive to change in the sense that management actions and other forces can readily influence its behaviour (Wedeles and Williams 1999; Johnson 2000). Indicators that are resistant to change despite actions to improve their performance are not useful in sustainability analyses. An example of a highly sensitive indicator is 'soil carbon pool decay rates' in relation to global cycles.

An example of a low-sensitivity indicator is ‘total employment in all forest-related sectors’ in relation to societal benefits.

- *Predictability* – future indicator levels must be predictable with reasonable accuracy if they are to be of use in an adaptive management context. Past indicator performance is seldom a sensible reference for future behaviour (CSA 1996; Wedeles and Williams 1999; Johnson 2000). An example of a readily predicted indicator is ‘mean annual increment’ in relation to ecosystem productivity (criterion 2). An example of a totally unpredictable indicator is ‘expenditure on international forestry’ in relation to society’s responsibility for sustainable development (criterion 6).
- *Understandability* – indicators must be understandable not only to forest managers, but also to the informed public, especially if public interests are to be incorporated into forest planning exercises (Wedeles and Williams 1999; Johnson 2000). Simplicity and clarity are also characteristics that increase an indicator’s understandability (CSA 1996). An example of a highly understandable indicator is ‘water quality’ in relation to soil and water (criterion 3). An example of an indicator difficult to understand is ‘index of the diversity of the local industrial base’ in relation to societal benefits.
- *Measurability* – indicators are of no use unless it is possible to obtain objective empirical measurements of their state over time (CSA 1996). The data may be already collected for other purposes, or may need to be collected specifically for the purposes of gauging SFM progress for the local forest in question. An example of an easily and directly measured indicator is ‘crown transparency’ in relation to ecosystem productivity. An example of a difficult-to-measure indicator is ‘extent to which forest planning and management processes consider and meet legal obligations with respect to duly established Aboriginal and treaty rights’.
- *Validity* – indicators must be measured in a manner that is both consistent with scientific understanding, and technically valid. The data must be objectively obtainable and reproducible (CSA 1996; Wedeles and Williams 1999). An example of an indicator with high validity is ‘area and severity of forest fires’ in relation to ecosystem productivity. An example of an indicator with low validity is ‘mutual learning mechanisms and processes’.
- *Targets/Thresholds* – indicators have their strongest meaning when forest managers are able to set objectives or targets for their performance, and subsequently to design management actions to induce indicator performance toward the chosen objectives or targets. If it is impossible, or at least very difficult, to know or agree on what would be considered good or bad performance in an indicator, then it has low relevance in SFM. An example of an indicator for which it is easy to set a target or threshold is ‘area of forest permanently converted to non-forest land use’ in relation to global cycles. An example of an indicator for which setting a target or threshold is nigh impossible is ‘economic incentives for bioenergy use’ in relation to global cycles.

In my experience, few indicators measure up well against all or most of these quality traits. I believe it is paramount in any C&I-SFM endeavour to apply such a quality test to all indicators early in the process, partly to help reduce the set to a manageable number (most indicator sets are too large for strong work on all indicators), and partly to make people aware of the key weaknesses of the indicators they retain and use.

5.5 Generating indicator data

I have been unable to find any literature that comprehensively describes the characteristics of good data to report on indicators of SFM. Some may find it difficult to separate the act of

evaluating indicator quality from that of evaluating data quality, but I have found it both possible and useful. The six characteristics outlined below were derived for a recent assessment of indicator data reported in the state-of-the-forest report for the Eastern Ontario Model Forest (Johnson and Heaven 1999).

- *Currency* – data associated with each indicator must be current and up-to-date. Historical data sets that are disconnected from the present are of little use in assessing progress in SFM. For example, a forest inventory from the 1970s would be a poor data source for gauging ecosystem diversity in the year 2000.
- *Directness* – this relates to how close the measurement instrument is to the real phenomenon of interest. Direct data are obtained close to the phenomenon measured (e.g. physical measurements of leaf area index), whereas surrogate data are produced indirectly (e.g. remote sensing to gauge leaf area index). Direct data are always preferred, but may at times become impractical when spatial scales are broad.
- *Precision and Accuracy* – precision refers to the closeness of repeated estimates of central tendency (e.g. mean) to the true population value. Thus, precise data are distributed narrowly around the mean. Accuracy refers to the nearness of the sample mean to the true population mean. Imprecise data will often provide a larger margin of error, and inaccurate data will often result in some form of bias.
- *Scale Quality* – this refers to the nature of the scale used to measure data. Data exist in one of four possible forms: ratio, interval, ordinal, or nominal. Ratio data (e.g. mass, volume) have a constant interval size regardless of the unit of measure and a true zero. Interval data have no true zero, but instead has an associated arbitrary zero (e.g. degrees C temperature). Ordinal, or rank, data consist of relative rather than quantitative differences in intervals. Thus, in ordinal data, the distance between items ranked is unknown, and may be unequal. Nominal data consist of attributes. They are classified according to the possession of some quality rather than a quantitative measure. Colour is measured nominally (e.g. red, blue). Ratio data are the most desirable since they can be manipulated using the greatest array of mathematical operations. When an indicator offers more than one scale choice, it is best to be as close to ratio as possible.
- *Spatial and Temporal Scale* – it is important that each indicator be measured using an appropriate spatial and temporal scale. Examples of spatial scales include stand- and landscape-level measurements. Examples of temporal scales include the yearly measurement of growing-stock depletion due to timber harvesting, and the thousands of years used in the measurement of geological events.

In summary, it is important to pay attention to these data traits so that high-quality indicators can actually be used to gain reliable and high-quality information. It is frustrating to see reports that use high-quality indicators but report rather bad data. Of course, equally frustrating is to see examples of bad indicators for which the data are actually rather good. Unfortunately, these two situations appear frequently in sustainability reports. Worst, and thankfully rare, are instances where low-quality data are reported for a low-quality indicator.

5.6 Conclusion

While there has been significant progress in developing and testing C&I-SFM in Canada and elsewhere, I believe we are stuck in a situation where our anxiousness and desire to report some progress is overwhelming our interest in trying to report the situation accurately. We must fix the problems outlined above, or C&I-SFM work will ultimately be dismissed as a sink for huge amounts of time, energy and money.

6. An Example: Biodiversity Indicators for an Alberta Forest

6.1 Introduction

The Biodiversity Assessment Project (BAP) is a series of studies aimed at developing and testing models for use in forest management planning for assessing whether particular facets of biodiversity are being conserved. BAP started at Lakehead University in 1995, and involves the following partners:

- Millar Western Forest Products (MWFP) Ltd. of Whitecourt, Alberta – representing the major client and funding source;
- Lakehead and Dalhousie Universities – my academic home bases;
- KBM Forestry Consultants Inc. of Thunder Bay, Ontario – which has taken over much of the BAP modelling work since 1998; and
- Sustainable Forest Management Network – a federally funded research network which has provided funding to BAP.

MWFP approached me in late 1994 to develop and apply wildlife habitat models in support of its ongoing efforts in responsible forest-management planning for its public timber lands in Alberta. In agreeing to undertake the work, I encouraged the company to consider not only the species elements of the overall biodiversity spectrum, but also ecosystem or landscape elements as well. The genetic aspects of biodiversity are not included in BAP, but tree gene pools are being examined by other experts using their own approaches. Thus, the objectives for BAP are to:

- develop a process-based spatially explicit landscape model to explore spatio-temporal variation of landscape patterns under probable simulated natural disturbance regimes;
- develop biodiversity indicator models appropriate for assessing MWFP's forests landscape patterns, ecosystem diversity and wildlife habitat carrying capacity;
- assess performance of these indicators against a range of forest-development forecasts; and
- advise the company on interpretation of the assessment, design of a promising forest-management strategy and plan, implementation of a sound research and monitoring program for forest biodiversity, and further operation and development of the assessment models.

BAP was designed consistent with well-established frameworks for natural resource management (e.g. Walters 1986) and environmental assessment (Duinker and Baskerville 1986). The framework for the biodiversity assessment (Duinker et al. 1997) is as follows:

1. Data inputs for forest projection model:
   - forest inventory complemented by an ecological classification;
   - yield curves and succession rules;
   - natural disturbance history data;
   - forest-management strategies (rules and constraints at the stand and landscape levels); and
   - infrastructure (road, seismic lines, etc.) development plans.
2. Forest projection:
   - simulation of landscapes under probable natural disturbance regime conditions using the process-based spatially-explicit LANDIS model (Mladenoff et al. 1996);
   - generation of forecasts of the forest attributes under management strategy rules and constraints, and assumptions about yield development and succession using the spatial growth and harvest model GIS-Complan (Simon Reid Collins 1995); and

- forecasts stretching 200 years into the future; BAP uses 10-yr snapshots of the predicted stand attributes.

3. Biodiversity assessment:
   - creation and use of biodiversity models to interpret the forest attribute forecasts in terms of landscape pattern, ecosystem diversity (coarse filter) and species-specific wildlife habitat suitabilities (fine filter).

4. Interpretation:
   - analysis, comparison, and evaluation of biodiversity indicator forecasts for each strategy tested. Comparisons are made in the light of natural ranges of variation under the simulated natural disturbance regime; and
   - reformulation and retesting of management strategies. This process continues until an acceptable management strategy is achieved.

6.2 BAP structure and components

BAP is organized as follows (Duinker et al. 1997). Each of the three aspects of biodiversity (landscape, ecosystem and species) is a separate module of the analytical model core. These modules receive information from the stand attribute table which is spatially linked to the stand GIS coverage. The stand attribute table, in addition to the AVI (Alberta Vegetation Inventory) attributes, includes habitat structure variables either directly obtained from the growth/harvest and the natural disturbance regime (NDR) simulators or indirectly obtained from special habitat element (SHE) models. In the SHE models, we are building relationships between within-stand habitat structure elements deemed important for the selected wildlife species and simulated stand structure variables using Temporary Sample Plot (TSP) and Permanent Sample Plot (PSP) data.

To provide a benchmark with which outputs from the different forest management scenarios will be compared, the model LANDIS developed by Mladenoff et al. is being used (1996). LANDIS is a spatially-explicit process-based model designed to simulate landscape change over long period of time. There are two main modules in LANDIS: a succession module; and a disturbance module. Since fire is the major disturbance factor in MWFP's territories, land-type susceptibility to fire has been analysed by combining the fire history spatial database, the lightning-strike spatial database, the ecological classification, and the topography (aspect, slope, and elevation) using a digital elevation model.

The ultimate goal of the whole exercise is to provide guidance to MWFP in making a forest management plan by comparing scenarios. The scenarios compared in a first run were:

- business-as-usual (BAU), where the silvicultural intensities and the spatial layout of harvest blocks would remain for the entire simulation as they have been in the recent past;
- intensive two-pass (I2P), holding the spatial layout as in BAU, but intensifying silvicultural inputs and treatments to grow quality wood faster;
- adjusted spatial pattern (ASP), holding silvicultural intensity as in BAU, but abandoning the traditional 2-pass harvest block layout scheme and letting the wood-supply simulation model determine best harvest block sizes and locations;
- enhanced timber production (ETP), combining the changes in both I2P and ASP;
- a simulation from the wood-supply model with no timber-management activities; and
- a simulation using LANDIS.

Second-round scenarios have been fewer and more-refined versions of ETP, given that the company is committed to raising the long-term wood supply from its forest-management agreement areas and also to biodiversity conservation.

6.3 BAP indicators

6.3.1 Species habitat suitability analysis

We have decided to analyse the forest in terms of future habitat potentials for a small yet diverse array of vertebrate species. Original intentions were to limit the number of analysed species to about 10–12, mainly for tractability. The species-selection procedure (Doyon and Duinker 1997), where most of the vertebrate species were ranked according to ecological and socio-economical factors, then led to a spectrum of about 22 vertebrates. For each species, a habitat suitability index (HSI) model was drafted (Doyon and Duinker 1998). Some of these have a spatial component and some do not. In the second phase of habitat analysis, HSI values are smoothened by species home range (see Daust and Sutherland 1997). In the future, it is hoped to assess habitat connectivity using home ranges as the unit of evaluation, and also potential animal dispersal using a random-walking model.

Peer review of the HSI models during 1999 resulted in concentration of HSI work, for a variety of reasons, on four chosen species – little brown bat (*Myotis lucifugus*), gray wolf (*Canis lupus*), wood frog (*Rana sylvatica*) and beaver (*Castor canadensis*). Model development and testing for three other species have been put on hold temporarily because of time constraints – deer (*Odocoileus virginianus*), elk (*Cervus elaphus*) and caribou (*Rangifer tarandus*). Species for which we are modelling habitat supply in support of creating a biodiversity-favourable management plan include:

1. barred owl (*Strix varia*);
2. brown creeper (*Certhia americana*);
3. least flycatcher (*Empidonax minimus*);
4. lynx (*Lynx canadensis*);
5. marten (*Martes americana*);
6. moose (*Alces alces*);
7. northern flying squirrel (*Glaucomys sabrinus*);
8. northern goshawk (*Accipiter gentilis*);
9. pileated woodpecker (*Dryocopus pileatus*);
10. ruffed grouse (*Bonasa umbellus*);
11. snowshoe hare (*Lepus americana*);
12. southern red-backed vole (*Clethrionymys gapperi*);
13. spruce grouse (*Dendragapus canadensis*);
14. three-toed woodpecker (*Picoides tridactylus*);
15. varied thrush (*Ixoreus naevius*).

6.3.2 Ecosystem diversity and landscape configuration analysis

In BAP's ecosystem analysis, we track the proportion and diversity of stand working groups and habitats. Because different analyses might require a different level of distinction among the units, a hierarchical habitat classification procedure has been used (Doyon 1997). It first separates terrestrial and aquatic habitats, and then uses structural stages and composition for the terrestrial habitats. Riparian habitats are identified by creating a buffer zone around the aquatic habitats. Moreover, since working-group analyses do not allow tracking the fate of minor co-occurring species, a tree-species-specific tracking has also been implemented for individual tree species density as well as spatial distribution. Finally, we track area-weighted average stand age. Thus, our ecosystem diversity analyses include the following indicators:

- area-weighted stand age;
- working-group areas and spatial distributions;
- habitat-type areas and spatial distributions; and
- tree-species presence and distributions.

In choosing indicators of forest sustainability in terms of landscape configuration, we wanted to capture those that reflect critical states of fragmentation. Habitat types are used in this analysis. Early choices for indicators for measuring landscape configuration were numerous, but we soon realized that tractability would be paramount given the huge computing tasks that faced us in undertaking the overall biodiversity assessment. Thus, with considerable anguish and debate over what to keep and what to leave out, we settled on the following metrics:

- contrast-weighted edge density; and
- mean edge contrast index.

6.4 BAP in the context of C&I-SFM

Much has changed in the proverbial landscape of forest management in Canada since we started BAP. When we began our work, both the national C&I-SFM (CCFM 1995) and the CSA (1996) SFM Standard were still under development. The ISO 14 000-series standard for environmental management systems was also still being worked up. We are now in 2000, and forest certification is a growing reality for many forest-management enterprises. SFM is definitely here for a while as the reigning paradigm for forest use and management.

The original BAP client, MWFP, has decided to prepare a management plan for June 2000 that is as consistent as possible with concepts embodied in both the ISO 14 000 standard and the CSA SFM standard. As yet, though, indicators for only two of the six of the CCFM (1995) C&I-SFM –biodiversity and societal benefits – are being systematically forecast and subsequently monitored. This does not mean that MWFP is not addressing the other four criteria in some way –it is, through a variety of so-called impact assessment groups which have researched their respective themes and provided guidance to the company on how to manage the public forest to conserve specific forest values.

7. Conclusions: Ways to Continue the Progress

The long road of progress is difficult, but, as the maxim goes, if it were not difficult, it would be neither worthwhile nor fun. In my view, the needs during the next decade for really exciting progress in applying C&I-SFM to local-level forests can be summarized in the following ten points. So, here is my advice to practitioners and other participants who want genuine measurement of progress in the elusive pursuit of forest sustainability:

1. Be clear on definitions and conceptions of terms. Multiple conceptions for specific terms are not problematic as long as people know which conception is being used in a specific context;
2. Sort indicators into functional groups of context, action and condition/response indicators, cluster them around key issues in SFM, and support indicator data collection programs with strong systems analyses;
3. Apply discipline in naming indicators, with no excess wording and no reference points;
4. Seek balance among economic, social and ecological indicators;

5. Apply rigorous quality tests to indicator proposals before application;
6. Pay attention to data quality when measuring chosen indicators;
7. Recognize the powerful role of politics in C&I-SFM work and use negotiation-based participatory approaches;
8. Keep indicator sets small (small is beautiful!) – it is better to leave some important phenomena unmeasured than to distribute effort so widely that nothing is indicated with any confidence or utility;
9. Communicate vigorously and effectively; and
10. Use C&I-SFM as a means to an end. The end is surely genuine SFM.

We owe society and nature nothing less than the very best that professionalism in scientific and political endeavours can offer. The world's forests, in any such state as they might be today, are too precious for us not to know well whether sustainability is being fostered.

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Rural Community Assessments Applying Criteria & Indicators for Sustainable Resource Management

Charles C. Harris, William J. McLaughlin, Dennis R. Becker and Erik A. Nielsen

College of Natural Resources, University of Idaho
Moscow, ID, USA

Abstract

Scientists currently are challenged to comprehensively assess the social and economic effects of large-scale management actions, such as those proposed for salmon recovery on the Lower Snake River in the Pacific Northwest of the USA. Similar challenges are posed by obtaining and applying information on impacts on rural communities across large landscape-level regions and multiple political boundaries that can be used for the development of criteria and indicators for managing the region's forests in a sustainable manner. This paper presents a process for gathering and using data for socio-economic criteria and indicators (C&I) that is based on recent research conducting community-based resource assessments in the Pacific Northwest. It focuses on socio-economic criteria and indicators and presents research that represents one approach for implementing a process for operationalizing and assessing these C&I, detailing an in-depth public involvement strategy for current controversial Federal resource-management efforts in the USA. These include (1) planning for sustainable ecosystem management in the Pacific Northwest, and (2) evaluating alternative actions for recovering runs of wild salmon on the Lower Snake River in southeastern Washington state. In the first study (conducted in 1995 across a five-state area), a random sample of 198 rural towns were studied with 'community self-assessments' as part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) Scientific Assessment. The results of the assessment refute previous findings that less adaptable communities are necessarily ones whose economies were dependent on timber. However, the assessment results support other findings, such as that communities in the region with a high 'capacity to adapt' to on-going change (i.e. ones rated as being more resilient in the present research) were found to be larger in population. The second study built upon methods pioneered on the first study. Alternative Federal actions were assessed that ranged from maintaining existing water, hydroelectric, irrigation and recreation systems to breaching four dams on the lower Snake River. The paper

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concludes by addressing the implications of this analysis for developing useful social and economic criteria and indicators, and for applying them to better inform policy makers confronted with highly controversial management efforts like sustaining natural resource systems and endangered species in large landscape-level regions.

Keywords: sustainable forest management, Criteria and Indicators, social impact assessment, salmon recovery, Interior Columbia Basin Ecosystem Management Project

1. Introduction

A central question addressed by current forestry research and management is "how do we define, assess and achieve sustainable forest management?" The concept of sustainable forest management has been evolving over the last century, with concerns about managing public forests and wildland areas increasingly focused in recent decades on ensuring that a diversity of forest values are being recognized and adequate actions taken to monitor and maintain them. With increased understanding and changing community attitudes, management practices are being developed to conceptualize a broadened understanding of sustainability and then to operationalize and implement strategies for sustainable forest and resource sustainability.

Similarly, significant challenges are posed by obtaining and applying information on impacts on rural communities that can be used for the development of criteria and indicators for managing the region's forests in a sustainable manner. Scientists are especially challenged by the need to comprehensively assess the social and economic effects of large-scale management actions, such as those proposed for recovering endangered species like wild stocks of salmon on the Lower Snake River in the Pacific Northwest of the USA. These potential impacts range from the loss of cheap transportation for farm crops, if dams on the main river are breached, to continued restrictions of timber harvesting to improve salmon habitat in up-river forests. Obtaining and applying information on these kinds of impacts at the community level but across large landscapes that transcend political jurisdictional boundaries can be especially daunting.

This paper addresses these challenges and presents a process developed for gathering and using data for socio-economic criteria and indicators (C&I) based on community-based resource assessments in the Pacific Northwest. These community-based assessments were conducted as part of larger planning and feasibility-study projects being conducted by public resource-management agencies in the Pacific Northwest. The paper begins with a discussion of sustainable forest management and the role of criteria and indicators in monitoring and evaluating success in achieving sustainable forestry, as well as ecological and social conditions. It then focuses on socio-economic C&I, describing research that represents one approach for implementing a process for operationalizing and assessing these C&I. In so doing, it suggests a public involvement strategy for current controversial Federal resource-management efforts in the USA, such as planning for sustainable forest management and evaluating alternative actions for recovering runs of wild salmon on the Lower Snake River in southeastern Washington State. Strengths and weakness of this community-based C&I approach to social impact assessment are compared with traditional methods. The paper concludes by addressing the implications of this analysis for developing useful social and economic criteria and indicators, and for applying them to better inform policy makers confronted with highly controversial efforts, such as restoring endangered species in large forested wildlands.

2. Applications of Criteria and Indicators in the Inland Northwest of the USA

This paper first describes the region under study and the resource management issues in the Inland Northwest of the USA to which C&I can be applied for the study, monitoring and evaluation of the use of those resources. Traditional data for social and economic criteria and indicators (C&I) often are of limited breadth and depth for identifying and understanding impacts of sustainable resource management on rural communities. The paper describes case studies that provide an approach for operationalizing and assessing C&I under circumstances of especially controversial management issues.

2.1. The region, its resources, and management issues

The area under study in these case studies encompasses the Interior Columbia and Snake River basins, a region of the northwestern USA that spans several sub-basins and their component watersheds across southeastern Washington, eastern Oregon, and central and southern Idaho. It encompasses a varied landscape that extends from the western reaches of the Columbia Plateau in central Washington and Oregon, eastward to the Bitterroot Mountain range in north central Idaho, and south through the central Idaho mountains to the middle and upper stretches of the Snake River in southern Idaho. It includes the Palouse in north central Idaho and eastern Washington, across the Clearwater, Snake and Salmon River valleys and the Camas Prairie in central Idaho. The basin's natural resources include some of the richest farmland in the world on the Palouse and Camas Prairie, prime timber lands in the Clearwater and Bitterroot Mountains, rivers harnessed by dams for power generation and reservoir recreation, including the Snake and Clearwater Rivers and their tributaries, and rangelands that traditionally have supported cattle and sheep grazing. Its watersheds also include old-growth forests in the Clearwater, Nez Perce, Umatilla, Boise, Sawtooth, Salmon and Targhee National Forests, as well as natural flowing rivers and pristine streams inhabited by trout and salmon, wilderness, and a diversity of wildlife (deer, elk, moose, bear and cougar) found in few other places.

This region also includes human communities as varied and unique as the landscape in which they are located. These communities include cities that are population centers with diverse economies, towns that are dependent on dry-land farming or ranching, and still other towns dependent on irrigated agriculture. They also include timber towns that range from ones with a strong pioneering heritage to others suffering the growing pains of a 'New West' economy of tourism and retirement in-migration.

In recent years, a variety of issues concerning the natural environment in the region, its management, and their relation to the region's communities and socio-economic development have been approaching a critical point. These issues have important implications for the region's future, its quality of life, social well being, and environmental quality, and they currently are the potential source of major conflicts and significant controversy in the basin. Issues of current concern include:

- Agricultural practices and the economic impacts of their regulation for air and water quality;
- Forest ecosystem management issues, including forest health, the proposed reservation of roadless areas on several national forests in the basin by the USDA Forest Service and its effects on the region's timber supply, and efforts to mitigate the impacts of deteriorating logging roads on water quality and fauna in those forests;
- The Forest Service's initiation of a process for revising the forest plans for national forests in the region;

- Regulatory and management actions related to the Endangered Species Act and other environmental laws – the most controversial of these is the restoration of wild salmon runs on the Lower Snake River, resulting in consideration of the feasibility of breaching of four dams on the river by the US Army Corps of Engineers; and
- The impacts of all of these actions – and especially reduced and changing resource supplies and uses of public lands – on the region's economies, residents, and their communities' way-of-life customs and culture, and ultimately their quality-of-life and social-wellbeing.

Issues like these are perceived by citizens of the region to be vital importance for their future and that of the landscapes in which residents live and work. The sustainability of the basin's economy and the well being of its communities are of particular concern, as well as other associated impacts of resource use and management on environmental protection and community development.

2.2 Socio-economic C&I (SECI) for sustainable forest management

Primary data collection and analysis were combined with analysis of secondary data and processes of public involvement in two projects whose goals were to increase public participation in the assessment process. These projects provide a blueprint for designing and implementing effective processes to help assess socio-economic criteria and indicators (SECI). The intent of C&I systems is to provide a framework for describing, monitoring and evaluating progress towards the achievement of sustainable forest management. Of all the criteria and standards proposed in the various systems of C&I, however, the socio-cultural and economic impacts of land management activities seem to be the most problematic and difficult to assess. One example is the set of SECI established in the Montreal Process, which has been elaborated in national-level frameworks for gathering, analysing and evaluating information in an effort to relate the ecological conditions of forests to economic and societal well-being.

The methods described here suggest an overall approach for developing and implementing processes to achieve a number of these C&I for socio-economic conditions. These SECI, as defined in the Montreal Process, specifically are ones concerned with, first, the maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies. Indicators for this criterion include ones related to a diversity of needs and benefits, including the value and volume of wood and wood products production, as reflected in size of industry and amount of employment relative to a community's overall workforce. These indicators also include one of employment and community needs, the viability and adaptability to changing economic conditions of forest dependent communities, and recreation and tourism (such as the area and proportion of forest land managed for habitat protection of salmon spawning areas for production of salmon for sport-fishing). These indicators also include cultural, social and spiritual needs and values, such as the area and proportion of forest land managed to protect the possible range of cultural, social and spiritual needs and values (like those represented by Tribal values for salmon).

A second key SECI here is concerned with a legal, institutional and economic framework for forest conservation and sustainable management. Indicators for this criterion focus on the extent to which existing frameworks, both legal and institutional, support the conservation and sustainable management of forests. In particular, they focus on the extent to which those frameworks provide for periodic forest-related planning, assessment, and policy review. They also seek to ensure public access to information, promote opportunities for public participation in public policy and decision-making related to forests, and manage forests to conserve special

environmental, cultural, social and scientific values. Application of social and economic data, and in particular the results of public input efforts, to planning with these kinds of C&I require that analysts first gather sound and applicable socio-economic data. They also need to choose key C&I for assessing socio-cultural and economic impacts, make reasonable and defensible assumptions about those impacts and their relation to various management alternatives and activities, and, finally, develop measurable standards for forecasting probable impacts and then later, after project implementation, for monitoring actual impacts.

3. Interactive Community Forums for Social Impact Assessment in Rural Communities

New approaches for better attaining data and input for the kinds of SECI detailed above are needed. This section focuses on one new approach that uses the perceptions of community residents to identify the social, cultural and economic impacts. In this section and those that follow, techniques used to solicit residents' perceptions are described, and then their results are described and assessed.

Key to these efforts is an expanded use of more effective public-involvement techniques. Approaches traditionally used by land-management agencies to use public involvement have made little effort to solicit the concerns, perceptions and judgments of community residents and then integrate them into social impact assessment (SIA) processes. Although the role individuals have played in various assessment processes have differed, typically people have provided minimal input, and what input they have provided traditionally has represented an informative or consultative role (Arnstein 1969; Burdge and Robertson 1990; Freudenburg and Olsen 1983; Krannich et al. 1994). More recent collaborative approaches (Friedmann 1987, 1992; Healey 1997) have greatly expanded the roles of the public in the assessment process and the techniques used to elicit their input.

One recent approach that has been developed and implemented in several large-scale assessment projects is the Interactive Community Forum (ICF) process (Harris et al. 1999). The ICF process was developed by the University of Idaho for several projects assessing the impacts of land-management actions on communities across a multi-state region. They include a community self-assessment process for the US Forest Service and the US Army Corps of Engineers' environmental impact study for salmon recovery. The ICF approach builds upon techniques and methods outlined by the Interorganizational Committee on Guidelines and Principles (ICGP 1994), and in particular, ones used for 'scoping' the range of issues raised by the project being analysed and 'projecting' the likely effects of various proposed actions. In the past, SIA approaches generally have merely confirmed potential impacts with public input (Krannich et al. 1994). In contrast, the ICF processes described here identify community residents as the 'experts' (Reich 1985) and as a principle source for identifying potential impacts resulting from natural resource decisions. The intent of the ICF process was not to measure individuals' attitudes about what they thought about management alternatives or what they wanted to happen, but to measure their perceptions of what the impacts of those alternatives likely would be to their communities. In the case of salmon recovery on the lower Snake River, for example, a key premise of the research was that community residents possessed varying levels of knowledge pertaining to the issue, and further that some perceptions held were based on either misinformation or a complete lack of information. As described here, the ICF process sought to provide a forum for critical education (Diduck 1999; Freire 1970) and information sharing (Echabe and Castro 1999; Stasser and Titus 1985), whereby a more informed perspective of social impacts could be provided.

3.1 An assessment of small rural communities in the Interior and Upper Columbia River Basins for the Interior Columbia Basin Ecosystem Management Project's (ICBEMP) integrated science assessment

The Interior Columbia Basin Ecosystem Management Project (ICBEMP), a multi-agency resource-management planning effort conducted by the USDA Forest Service and USDI Bureau of Land Management, began in 1993. The ICBEMP region includes the lower Columbia River basin in eastern Washington and Oregon and the upper Columbia River basin (predominantly, watersheds of the Snake River), which span all of Idaho and western Montana and Wyoming. This project sought to provide a comprehensive and thorough assessment of socioeconomic conditions at the community level of scale, as well as an assessment of the natural resources in the region. ICBEMP has produced a broad management strategy for the region's public lands, as prescribed in the project's Environmental Impact Statement, which is now under review.

3.1.1. The ICBEMP community self-assessment process

The ICEMP project's Social Science Assessment Team recognized the need to look beyond the characteristics and conditions of the region's ecosystems and natural resources and examine the people and communities that are a part of those ecosystems and using those resources. Accordingly, as part of the Integrated Science Assessment, research was conducted in 1995 to better understand the characteristics and conditions of small, rural communities in the region. Data were organized and analysed for this component of the regional assessment that included in-depth social, economic and spatial data for the communities in the Interior Columbia Basin.

This research was conducted to facilitate a self-assessment by community members of the characteristics and conditions of small, rural communities in the Interior Columbia River Basin. Communities included in the assessment were ones under 10 000 in population within the basin. A total of 472 cities and towns are found in the region, of which 387 are incorporated small rural towns under 10 000 in population. Detailed social and economic data were gathered for the 198 small towns randomly sampled from the 387 rural communities in the basin. These data include the results of community self-assessment workbooks completed by 1350 key informants providing details on residents' perceptions of the economies, social attributes, quality of life, and other characteristics of their communities.

They also included the results of 198 community self-assessment workshops, which provided collective judgments of their communities' conditions and characteristics. The community self-assessment workshops were conducted to assess the perceived current conditions of each of the 198 sampled communities. These workshops were designed to help community members describe the characteristics of their communities and their aspirations for the community they lived in. Although each of the key informants was asked to participate in terms of a particular identified role, they answered questions and participated as individuals (i.e. they provided their own perceptions of current community characteristics and conditions). Most questions did not involve an expression of personal value, preference, attitude or opinion; they simply focused on the ways respondents perceived their town's infrastructure, people, economy, leadership, and orientation toward the future.

In addition to attending the workshops, each participant was asked to fill out a 'community self-assessment workbook' prior to the workshop, which asked questions relating to twelve 'critical dimensions', including: the attractiveness of the community, the attractiveness of the region surrounding the community, community cohesiveness ('sense of community'), community services and infrastructure, community autonomy, economic diversity, resource

dependence, community quality of life, strength of the community's civic leadership, and effectiveness of the community's government.

Key informants were identified using a modified snowball technique to generate a list of citizens who were both active in each community and knowledgeable about the social and economic conditions of their community. From this list, a purposive sample of eight informants was drawn from each community to represent a variety of backgrounds and viewpoints, and thereby approximate the range of community perceptions about the changing status of the community and its orientation towards the future. Specified types of active, involved community members included in the workshop were from civic groups, local government, business, and various community services. Detailed data from these workshops on, say, community autonomy and major factors contributing to its level in various communities provided an in-depth, comprehensive base of knowledge research.

A second database from this research includes economic data on community employment for all communities in the region. Economic profiles were developed for each of the 472 cities and towns in the ICRB using 1995 USA Census Bureau sources. These data provide a profile of each community's economy in terms of their total employment and income attributed to major industrial sectors within each economy. The profiles represent an updating and desegregation of 1992 employment and earnings data from the US Bureau of Economic Analysis' Regional Economic Information System (REIS) (US Department of Commerce 1994) and the US Forest Service's IMPLAN data (REIS data updated and estimated at the county-level for all counties in the study area). These data were then resolved and allocated to all 472 communities in the study area: the 387 small rural communities and, in addition, the other 85 cities (greater than 10 000 in population) and bordering communities in the region. This disaggregation was completed using local sources such as phone listings for businesses (compiled by Business America on CD-ROM for the third quarter of 1994) and recent directories of businesses for the relevant states. A total of 22 major industrial sectors were used in the economic assessment.

3.1.2 Results of the community self-assessment process

Examples of the kind of output available from this assessment process include a community's *economic diversity* and *community resiliency*. In the case of *economic diversity*, this construct was measured in terms of the mix of the types of industry and employment opportunities within the community; community key informants rated the overall diversity of the mix in their community in comparison with other small rural communities. This scale and the items comprising it focused on key informants' perceptions of their towns. To assess the actual economic situation in a town with an objective, empirical measure based on actual employment, an *economic diversity index* was calculated. This index was comprised of standardized measures of two indicators of the extent to which a community was dependent on employment in a wide variety of industries as opposed to only a few. The first component of this index was a measure of the average number of industrial sectors having some proportion of employment in that community, ranging from 0.04 for communities with employment in one sector (1/22 sectors) to 1.0 for employment in all sectors. The second component of the index was a measure of the preponderance of total employment in any one sector – the measure was first set at zero and then increased by one for each sector for which the proportion of a community's total employment exceeded one-third (33%). The higher this average, the less diverse the economy. Then, both measurements were summed for a cumulative index of economic diversity. Scores on this economic diversity index for all rural communities across the basin ranged from a low of –1.0 to a high of 1.0. Low economic

diversity ranged from –1.0 to 0.0, moderate from 0.01 to 0.3, and high from 0.31 to 1.0. The mean economic diversity score was 0.4.

Economic diversity is a key component of another construct characterizing a community's well-being and sound development: its *community resilience*. The concept of *community resilience* refers to a town's ability to manage change and adapt to it in positive, constructive ways, relative to other communities. A measure of this construct, termed the 'community resilience index' (CRI), was developed to indicate a town's likely response to change.

The CRI was based on an aggregate measure of residents' perceptions of key community characteristics and conditions. This index rated the 198 communities on the extent of their resilience. Components of the index included summary community scores on a number of dimensions of community conditions. The higher the index, the greater the community's resilience in comparison to that of other communities and the more vital, attractive, and healthy the community was compared to other communities in the region. The index was based on community characteristics critical to a town's capacity to adapt to future changes, including strong civic leadership, a highly cohesive social organization, local amenities and attractiveness, and a diversified or stable economy. These characteristics reflected or contributed to civic pride, excitement, and typically proactive responses to changes facing a community.

A community rated with the CRI as being highly resilient was thus one that was highly attractive and blessed with an abundance of outdoor amenities nearby; it also was characterized by a high level of civic involvement and effective leadership by its residents, and by social cohesion among its residents. The CRI score was an additive function of scales based on these dimensions. Total scores on this index for the 198 rural communities sampled across the basin ranged from a low of 240 to a high of 470. Low diversity community resilience scores ranged from 240 to 350, moderate from 351 to 400, and high from 401 to 470. The mean community resilience score was 380.

Each small town in the region is unique and interpreting patterns in their development and its relation to resiliency can be complicated. Generalizing about the kinds of towns that are resilient to changes must be sensitive to the effects of their unique, individual circumstances. In general, however, we found rural communities in the region to be more resilient than is commonly assumed. In particular, many rural towns perceived as being 'timber communities' by their residents are fairly resilient and healthy, especially in comparison to small ranching and farming communities. The face of these timber towns is currently changing as a result of their amenities, diversifying economies, and changing populations.

Not surprisingly, economically diverse communities, as classified according to their actual dependence on a variety of industries based on employment proportions, both have changed the most and are characterized by the highest CRI scores, while farming and ranching have changed the least and received the lowest CRI scores. In contrast, the rapid population growth of tourism/recreation towns has caused them to change significantly, but resulted in lower levels of resiliency. Nonetheless, larger proportions of communities in which outdoor recreation/tourism was perceived as a dominant industry are rated as fairly high in resilience.

The results of the current research on community resilience provide support for some findings of the 1993 assessment of coastal communities in the Pacific Northwest conducted by FEMAT (Forest Ecosystem Management Assessment Team; see USDA Forest Service 1994). The findings of the ICBEMP assessment refute the FEMAT conclusion that less adaptable communities were necessarily ones whose economies were dependent on timber. Moreover, the results of the more recent assessment do support other FEMAT findings. Communities in the Interior Columbia Basin with a high 'capacity to adapt' (ones rated as being more resilient in the present research) were found to be larger in population. Communities 'less able to adapt' (having lower levels of resiliency) were found to have a

less-developed infrastructure, a less diverse economy as measured empirically with an index of employment diversity, and to be more dependent on nearby communities. These findings mirror the conclusion of the FEMAT research for rural Westside towns.

Assessments of current characteristics and conditions of communities in the region, changes in them, and the major factors influencing those changes and community responses are critical for developing constructive, pro-active strategies for assessing and responding to change. Residents must deal with the realities and potentialities of their particular community and, to do so, they must have objective and accurate information about their town's current situation. This information can be important for developing more useful, measurable, and effective SECI, and for providing measurements of those C&I. Furthermore, using this process itself, or one like it, is an important step towards meeting key C&I concerned with adequate public involvement and input.

3.2 The Lower Snake River Community-Based Impact Assessment

A second community-based assessment process was developed for the US Corps of Engineers as part of its feasibility study and environmental impact assessment evaluating the socioeconomic, biological, and engineering feasibility of three alternatives for improving salmon migration through the four lower Snake River dams. That community impact-assessment process, which elicited residents' perceptions of the socio-economic impacts of the alternatives under study on their community, builds on the ICBEMP community assessment process described in section 3, refining and further developing it. It provides another model for implementing SECI and gathering data for monitoring with key social and economic C&I.

3.2.1 Restoration of wild salmon stocks in the Lower Snake River: an overview

Anadromous fish runs throughout the Pacific Northwest are in decline, with a 1995 National Research Council report estimating that 75% of the region's salmon stocks at risk of extinction. Currently, three stocks of Snake River salmon were listed as endangered in the early 1990s under the Endangered Species Act, and another anadromous stock, steelhead, was listed as threatened in 1997. The National Marine Fisheries Service (NFMS) produced a Biological Opinion in 1995 that initiated various activities of the Salmon Recovery Plan in the Snake River. It included the mandate that the Corps of Engineers study ways to improve juvenile salmon migration through the dams on the lower Snake River and prepare an environmental impact statement on the alternative actions under consideration, as required by the National Environmental Protection Act. One alternative continues the existing system of using barges to capture juvenile salmon and transport to the Columbia River, augmenting flows of water through the Snake River to help flush the fingerlings downstream, and enhancing fish guidance systems. A second alternative includes major system improvements (e.g. construction of surface bypass collection systems, turbine modifications, and fish guidance systems), and the third is the removal of the earthen portions of the dams, returning the river to its near-natural free-flowing state.

For the feasibility study and the EIA process, a socioeconomic study was conducted to identify and forecast the associated costs, benefits and social impacts of these alternatives. The study included multiple levels of geographic scope. On a national level, the Corps has evaluated the economic benefits and costs to the country. On a regional level of the three states of the Pacific Northwest (Washington, Oregon and Idaho), the Corps evaluated the

economic impacts in terms of jobs and income from the different alternatives. Economic impacts also were estimated for three sub-regions (combinations of counties classified as upriver, reservoir and downriver) and for specific communities within these sub-regions. The social analysis has examined those residents and communities that may be directly or indirectly affected by the alternatives under consideration.

3.2.2 Purposes and objectives of the Lower Snake River Community-Based Impact Assessment

As part of the social analysis, the Lower Snake River Community-Based Impact Assessment had two main purposes. First, the study assessed the current condition and characteristics of selected communities in southeastern Washington, northeastern Oregon and central and southern Idaho that potentially would be affected by alternatives for salmon recovery in the Lower Snake River under consideration by the US Army Corps of Engineers. The second purpose of the study was to assess community participants' perceptions of the kinds and extent of impacts each of the above alternatives would have on their communities. The results from the forums provide additional, more detailed information reported in the social assessment analysis and considered as part of the environmental impact statement and feasibility report (see Harris et al. 1999a; 1999b).

In particular, the objectives of the interactive community forums were to:

- Introduce community members to preliminary information from the Corps of Engineers' environmental impact statement and feasibility report to help them identify positive and negative social impacts;
- Understand communities' current situations and how they have changed since 1960;
- Provide residents with the opportunity to assess how their community would be affected by the three major alternatives under consideration; and
- Provide people with an opportunity to have their input included by the US Army Corps of Engineers as part of the environmental impact assessment.

3.2.3 Research approach and sampling design

The research approach taken for the Lower Snake Community-Based Social Impact Assessment was a multiple case study. The unit of analysis and the sampling unit was the community. The sampling frame was all communities located in one of the three impact areas designated by the US Army Corps of Engineers for consideration in the assessment. These areas included the reservoir region in southeastern Washington, the upriver region in north-central and southern Idaho, and the downriver region in northeastern Oregon and south-central Washington. The goal of this multiple-case study was to provide a forum for a community-based assessment of impacts of the project alternatives on a sample of 27 communities in the region comprised of these three impact areas. Each assessment was conducted during a one-day 4-hour public meeting in each of the communities. The forums enabled a team of social scientists to record local perspectives of past and current community responses to economic and social changes, and to assess potential social impacts resulting from the project on a variety of kinds of communities.

The communities of concern for this assessment included a total of over 200-plus communities within the geographic scope of the region. Given this large number of communities, it was not possible to adequately obtain sufficient information about each community within the timeframe of the decision-making process. Therefore, a range of

communities in which to conduct community-based assessments was selected, based upon a theoretical sampling approach whereby communities were selected based on a typology of predetermined criteria. Two variables, level of economic diversity and geographic location (i.e. a state of the USA) were used as the primary criteria for the initial theoretical sampling frame. Degree of economic dependence on various industries (e.g. trade, agriculture, wood products, etc.) also was considered in the sampling process.

All of the community forums were open to the general pubic, but, in addition, active and involved community members were targeted and asked to attend to ensure that a range of potential interests and important perspectives were represented at each forum. The research assumed that these individuals represented the full diversity of knowledge and perspectives within each community, and that they were among the community residents who were most knowledgeable and capable of addressing key issues that could impact the future of their community.

Non-residents of the sample communities were invited to attend the forums, but their participation was limited to providing general written comments to the Corps about the assessment process and the alternatives. A key research premise was that participants in the interactive groups at each community forum needed to be community members who possessed in-depth knowledge about their community.

3.2.4 The assessment process: conducting the interactive community forum

During the 4-hour workshops, participants were asked to assess their communities' current and potential situations by thinking about four major dimensions of community. These dimensions include the people (i.e. the social make-up of the community), the place (i.e. the community's built environment, natural setting, and amenities), the economy (i.e. its businesses and sources of jobs and wealth), and the community's vision and vitality (i.e. its governance, leadership, and civic involvement). Community dimensions and their role in community development were identified based on researcher expertise and literature reviews of previous research. They were used to help the respondents reflect and report on the social and economic dynamics of their town. The dimensions of community characteristics and conditions represent the elements of community used in the interactive forums. Using the latest research on the social, economic and biological effects of each of the three pathways, community participants engaged in a structured interactive process to identify likely social, cultural and economic impacts to their communities, as well as ways to minimize any negative impacts.

All of the individuals, who attended the community forums participated according to a set of interactive, structured group activities. These activities were designed to promote discussion across varying community viewpoints, introduce the best available information about primary and secondary impacts of the project, and record the thoughts and reactions of the participants.

These four broad dimensions of community characteristics and conditions represented the elements of community that were the focus of this discussion throughout the duration of the interactive forums. At the outset of each forum, the significant historic changes in each community, as related to each of the four dimensions, were recorded and shared with the entire assembly of participants as illustrations of each dimension.

Forum participants were systematically assigned to different facilitated tables based on self-reported community involvement roles (e.g. business, elected officials, land-production, education and health services, etc.). The purpose here was to maximize the diversity of community members in the group at each table. These participants were first asked to assess the

1999 current situation in their community in terms of the four dimensions of community. Sheets listing a fairly comprehensive set of characteristics or conditions related to each of the four community dimensions were reviewed to assist forum participants in, first, thinking about the specifics of each dimension. Second, they helped participants consider specific reasons or justifications for their ratings of their community based on particular characteristics or conditions of it. The facilitator at each table conducted an initial rating of each dimension with a rating form entitled, 'Your Community in 1999', with a current community situation scale ranging from 1 ('As bad as it could be') to 10 ('As good as it could be'). The purpose of this rating exercise was to stimulate forum participants to begin thinking about their community's situation in 1999 in terms of each of the four dimensions. With this starting point they would be better able to judge how things would change in the future (specifically, in the year 2020) if the Corps adopted any of the three proposed alternatives. This rating process also was intended to help the study team learn from forum participants about their community. Each form also obtained written responses from participants on the key or most salient characteristic or conditions for why they rated their community the way they did.

After several minutes of facilitated discussion of their numerical ratings of their community on a given dimension and the reasons for their ratings, participants were asked to re-rate their scale based upon what they had learned in their discussion. They were assured they could keep the same rating or change it. They then were reminded they needed to complete the second part of the question by filling in the blanks on the sheet with characteristics of the dimension from the corresponding sheet, or writing some other reason that was behind their rating. They were reminded that their written justifications were as important as the numeric rating they had given. The goal was to get them to justify their rating and explain the 'why' behind it, based on the characteristics they considered most important in making their decision. This process was followed to assess the current situation in 1999 for all four dimensions.

Information was then presented to community members on the forecasted biological, economic and physical changes associated with each of the three alternatives under consideration by the Corps. After presentation of the impact information, community members were asked to combine it with their knowledge of their community and forecast the likely effects their community would experience in 20 years (the year 2020). They did so using a community impact rating scale and again providing specific reasons or justifications for those ratings in writing.

An impact-rating scale was used by participants to indicate the kind and degree of change in each of the four community dimensions that would result if an alternative was implemented. These ratings were to be based on the presentation of information about each pathway by the study team and discussed within the groups at the facilitated tables. This community impact scale ranged from –5 ('adversely affected' by the pathway) to +5 ('beneficially affected'), with a mid-point, or '0', that was based on their rating for each dimension on the current community situation scale. Again, the process of discussing ratings, sharing reasons for those ratings, and the re-rating of the scales and the recording of reasons for their rating was repeated for each alternative.

3.2.5 Data entry, coding, cleaning, analysis, and reporting

The input from forum participants thus included both rating scores and written justifications for their ratings. The two types of data and their analysis in this report represent a direct matching of both the quantitative data (numerical scale ratings) and qualitative data (up to three characteristics for each community dimension or reason for the rating provided by participants as justifications for their rating). These responses were entered into a database

for each community. Once the data were entered, they were inspected for errors, and any found were corrected.

Standard procedures were followed for coding and analysing the assessment's qualitative data. These data consisted of open-ended responses to questions requesting that participants give reasons or community characteristics to justify their numerical rating of each dimension of community, whether for the current (1999) situation or for the changes or impacts they perceived would result from each of the three alternatives. Individual participant's responses were then coded descriptively and thematically. Patterns among these thematic categories were identified, and analytical generalizations from these patterns were made. The scale ratings, as well as themes and actual text of the reasons given, were analysed for each community to identify patterns across the groups of participants at facilitated tables at each community forum, as well as across communities in a cross-case analysis that compared results for all the communities assessed. This cross-case community comparison was conducted to identify patterns across the 18 communities in terms of their 1999 current situation. Its purpose was to identify those communities might be at greater risk from outside changes, based on both the quantitative and qualitative data. Salient justifications for the ratings were used to reinforce interpretation of the common patterns for the current (1999) situation. Likewise, in the analysis of the three alternatives, a similar process was followed to examine the forecasts participants made about changes to the community in the year 2020 due to each pathway.

3.2.6 Results

A primary result of this process was development of a typology of communities, or array of kinds of communities having common characteristics. This typology was used to understand the range of kinds of communities found in the region and potential impacts on them. Forum participants in agriculturally-based communities and trade-center cities closest to the Lower Snake River perceived the impacts of dam breaching on their communities to be the most severe and adverse due to increased transportation, utility, and other costs. Participants in agriculturally-based communities on the upper Snake River also perceived the impacts of dam breaching more negatively and as more likely to create adverse community effects than did participants from other upriver communities. Similar results were found for traditionally multiple resource-use communities in the upriver region in which irrigated agriculture and timber continue to play major roles. In contrast, participants in other multiple resource-use communities suggested they were likely to be directly and negatively affected by loss of wild salmon runs, and that the impacts of breaching on their communities would be most positive and beneficial. Similar results were found for upriver trade-center communities whose relationship to the lower Snake River is primarily indirect. Participants in those larger cities perceived the direct impacts on them to be a diminished quality of life and loss of community character if the current situation was maintained and no action taken to restore the wild salmon runs.

4. Opportunities and Limitations of Community-Based Assessment Methods for Socio-Economic C&I (SECI) for Sustainable Forest Management

The intent of C&I systems is to provide a framework for describing, monitoring and evaluating progress towards the achievement of sustainable forest management. The methods

described above suggest an overall approach for developing and implementing processes to achieve a number of these SECI. However, for data from these assessments to be useful and applied they must be linked to the SECI.

In the case of forest management, for example, an indicator developed as part of, say, a community resiliency criterion could focus on economic diversity. Measures of this diversity (as applied both in the community self-assessment processes and the index created from actual employment profiles) could be used to assess the resiliency of a local community. A standard of high, medium or low resiliency could be set for communities, and the affects of each alternative assessed in terms of economic diversity assessed – based on likely management effects of the alternatives and current levels of diversity of towns in the study area and its area of impact. This rating could then be included in the ratings of an alternative in terms of the economic and social dimensions of concern.

Opportunities for community-based assessment methods for socio-economic C&I present both strengths and weaknesses, advantages and disadvantages. On the positive side, these methods represent an in-depth, substantive, and collaborative approach to community assessment. The assessment of the realities of communities' current situations and how those conditions are perceived by community members can help in the maintenance and improvement of long-term multiple socio-economic benefits to meet the needs of societies. These focus especially on the economic, cultural, social, spiritual and recreation and tourism needs and values needs of forest dependent communities in ways that can help ensure their viability and adaptability in the face of changing economic conditions. These processes provide an approach for supporting existing frameworks, both legal and institutional, for the conservation and sustainable management of forests. The community self-assessment process thus can play an integral role in forest-related planning, assessment, and policy review, providing opportunities for meaningful and substantive public participation in public policy and decision-making related to forests, and ensuring the public's access to needed information.

One limitation of the impact-assessment methodology, and thus its findings, is that the results of this assessment must be interpreted, understood, and used within the qualitative and quantitative research framework. Care was taken, for example, in the Lower Snake Community-Based Social Impact Assessment to employ conservative statistical analyses, such as the use of median ratings within communities and replication logic, as opposed to sampling logic to make scientifically defensible inferences. The ratings presented were not deemed representative of the total population of the communities studied. Rather, they suggest the diversity of perceived effects and associated justifications from citizens who are actively involved in their communities or interested in the salmon recovery issue.

In addition, when the strengths and weakness of this community-based C&I approach to social impact assessment are compared with traditional methods, such as key informant interviews, secondary data analysis, polling, and survey research, other limitations must be recognized. When criteria including monetary and time expenditures and the necessary expertise of the facilitators are considered, this methodology must be deemed quite costly in comparison to others.

However, the value of this methodology for community-level assessment is likewise quite high if the involvement of local residents and a maximum public awareness of complex issues is a high priority. These methods can stimulate meaningful public dialogue and more careful, reasoned and informed judgment, as well as the education of members of the public – both by fellow community members and by experts conducting research on topics related to those judgments. The methods promote 'social learning' (Reich 1985), in that they promote the recognition of community members as community experts, promote participatory democracy and empower communities, facilitate community dialogue, and capture the diversity of community knowledge. In so doing, they increase the quality of public judgement that is

based on more complete knowledge and careful consideration of the consequences of different actions that might be taken (Yankelovich 1991).

Nonetheless, it is critical to stress that applications of the results of these methods can vary across communities and the geographic regions being assessed. The impacts and the communities assessed are unique, and each community has different capabilities to deal with distinct direct, indirect and perceived impacts. There may be common themes across all community types or within all community types, but there is not one single, 'one-size-fits-all' set of impacts across all communities. Nonetheless, efforts to incorporate C&I into this approach to action research, and further development of this research approach with attention to C&I, can enhance the inclusion of public values and perceptions for improved efforts for the conservation and sustainable management of forests.

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Field Testing Criteria and Indicators for Forest and Wood Workers in Ghana

I. Iorgulescu[1], J. Bowling[2] and R. Schlaepfer[1]

[1]Ecosystem Management Laboratory, Swiss Federal Institute of Technology, Lausanne, Switzerland
[2]Global Forestry Programme, International Federation of Building and Wood Workers, Geneva, Switzerland

Abstract

The social criteria and indicators developed at the international level must reflect the real needs of forest and wood workers. It is obvious that more attention has to be given to workers' issues to ensure that sustainable forestry truly covers the workforce. The paper presents the results of field tests in Ghana on worker criteria and indicators using a questionnaire format. The fieldwork was conducted in nine timber companies from five regions. Three specific questionnaires were targeted for the three parties we identified: management; workers' representatives; and workers. We performed a large number of interviews: nine with company representatives, twelve with union representatives, and 50 with workers. We conclude that indicators 'Wages and other benefits conform to national standards', 'Injuries and damages caused to human health are compensated in a fair, prompt and adequate manner', and 'Procedures are in place for dialogue and conflict resolution between management and other employees' are respected in the vast majority of cases. Indicator 'Forest employers take care of forest-related health risks for workers' is a critical indicator. Protection equipment and training may not correspond, in the authors' opinion, to international norms, to Ghanaian national standards, and with the collective agreement. Adherence to the collective agreement (not currently an indicator) forms a powerful mechanism for protecting the basic rights of workers and this should be included as a central indicator in the National Standards. The interview technique supported whenever possible by relevant documents is adequate for assessing workers' rights indicators as they are formulated in the Ghana Forest Standard. Based on our experience we make a number of proposals to refine the basic questionnaire used in the interviews. These include customising it for local conditions and making it very simple and concise.

Keywords: forest certification, sustainable forest management, social criteria and indicators, working conditions, questionnaires

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1. Introduction

1.1 Ghana – A general presentation

Ghana is situated in Western Africa, bordering the Gulf of Guinea, between Côte d'Ivoire and Togo. It occupies an area of 238 540 km^2. Population is estimated at about 18.9 million, with an annual growth rate of 2.05%, and a life expectancy of 57 years. The per capita GDP of US$1800 (purchasing power parity) is twice that of poorer Western African countries. The country is divided in ten administrative regions: Ashanti, Brong-Ahafo, Central, Eastern, Greater Accra, Northern, Upper East, Upper West, Volta, Western. The climate is tropical; warm and comparatively dry along south-east coast; hot and humid in south-west; hot and dry in north.

1.2 Forestry in Ghana

Forest with canopy closure greater than 40% occupies about 7% of Ghana's land area (Kotey et al. 1998). Most of this area is contained within the system of forest reserves. The timber industry is a very important sector of country's economy. The timber industry provides a sizeable share of the GDP (6%) and is a major employer. It supplies about 18% of export revenue, being the third largest contributor after gold and cocoa. About 75% of exports go to industrialised countries, especially Europe (UK and Germany being the major customers) and the USA. Log production is presently around 1 million m^3/year. An annual allowable cut of 0.5 million m^3/year can be sustained from forest reserves (estimation by Forestry Department). Prior to 1994, off-reserve production was effectively sanctioned by forest policy that allowed the progressive utilisation of the forest resources without replacement. Non-timber forest products and other services also play a very important role for the economy and, more generally, for the local populations.

The government controls forest policy in Ghana. The landholding communities (represented by their chiefs) own Forest reserves, but the Forest Department on behalf of the government manages them. While the establishment of forest reserves does not affect land ownership as such, management and control of land on reserves is, by law, exercised by the Forestry Department. Outside reserves, all timber resources are vested in the state in trust for the owners. Starting from 1994 an increased preoccupation for including major stakeholders, in particular local communities, in the decision making process is apparent. The main objective of the forest sector is "the conservation and sustainable development of the nation's forest and wildlife resources for maintenance of environmental quality and perpetual flow of optimum benefits to all segments of society" (MLF 1994).

1.3 Forest certification in Ghana

The timber sector has become increasingly aware of the trend, manifested on the markets from major industrialised countries, towards eco-labelling and forest certification. Certification schemes were intended to offer a voluntary, market-based alternative to boycott and other discriminatory measures, in order to promote the sustainable use of forest resources. At the same time governmental authorities perceived forest certification as one of the tools for achieving sustainability.

A national workshop held in Kumasi in 1995 concluded that a certification scheme should be developed in Ghana and that an independent, international body should approve the performance standards set by a national certification committee (Kotey et al. 1998). The

views that the existing cost of forest management should not be significantly increased by certification, and that beneficiaries should pay for certification were also expressed. A National Certification Committee, including major stakeholders was created soon afterwards. It should be noted that the labour movement, that is the TWU of TUC, was recognised as a stakeholder, and represented in the National Committee.

A standard entitled "A System for Quality Management for Ghana's Forests" (MLF 1999), covering all types of forestlands and providing the minimum performance levels to be achieved, has been developed. This standard explicitly includes criteria and indicators related to forest workers rights. Section 2: Principles, Criteria and Indicators under §6.8 (Implementation of the Forest Management System shall be Guaranteed), proposes the following criterion:

6.8.2. Rights and responsibilities of organisations and workers are outlined and guaranteed.

In the framework of the Ghana Forest Standard indicators are defined as quantitative, qualitative or descriptive measures that, periodically measured or monitored, indicate the direction of change. The following indicators were selected to guide the achievement of the above criterion:

6.8.2.11 Forest employers take care of forest-related health risks for workers.
6.8.2.12 Wages and other benefits conform to national standards.
6.8.2.13 Injuries and damages caused to human health are compensated in a fair, prompt and adequate manner.
6.8.2.14 There is a procedure for dialogue and conflict resolution between management and other employees.

However, no specific indications are given with regard to how to measure or monitor the above-mentioned indicators, especially concerning verifiers. A verifier is data or information that enhances the specificity or the ease of assessment of an indicator. Verifiers provide specific details that would indicate or reflect a desired condition of an indicator. They may define the limits of an acceptable zone (performance threshold/target). On the other hand, they may also be defined as procedures needed to determine satisfaction of the conditions postulated in the indicator concerned.

In our interpretation, conformity with the national labour legislation is the acceptance threshold that is implicit in the Ghanaian process indicators concerning workers' rights. The Ghanaian process is initiated and directed by the government. It is unlikely that government and other 'first level' stakeholders such as the timber industry or the traditional authorities would be willing to go beyond this standard, especially as the labour movement is considered only a 'second level' stakeholder. Higher standards would almost certainly imply higher costs that could impair the competitiveness of the timber industry. The stated objective of compatibility with major international initiatives does not seem to imply tighter standards, as the Ghanaian process is rather at the forefront on this issue (i.e. other initiatives do not take explicitly into account workers' rights).

In 1998 a national forest certification seminar was jointly organised by the TWU, IFBWW and Swedish Wood Workers Union and held in Kumasi. The seminar resolution expressed strong support for forest certification and demanded a stronger participation of labour representatives in the process (TWU/IFBWW/SWWU 1998).

The Ghanaian forest certification process is now at a critical stage. Before it will be fully operational, the National Forest Standard has to be tested in the field, which could bring further adjustments. At the time we visited Ghana, such a field test with the participation of international experts was planned for October-November. However, international markets will ultimately decide the future of forest certification in Ghana. This was quite clear during the discussion we had in Accra with the representatives of the Forestry Department and the

National Certification Committee. During the discussions, these officials expressed preoccupation concerning the bearing of certification costs and the use of certification as a tool for discriminating against Ghanaian timber products.

2. Objectives of the Study

The main objective of this study is to test a methodology concerning the assessment of the indicators related to workers' rights as they were formulated in the 'Ghana Forest Standard'. A closely related objective is to propose, where necessary, improvements to the considered methodology. A third objective is to inform national and international certification processes about workers' rights related criteria and indicators, and the procedures to assess them. The information gathered during the study can also bring elements to assess more generally the situation of timber and wood workers in Ghana.

A marginal objective is to assess how the certification process is perceived by some of the stakeholders (i.e. workers, trade union representatives, and management). We are more specifically interested in worker rights criteria, and their possible impact on relations between employees and their employer.

3. Methods

One of the main issues in the certification process is that of indicator selection and assessment. Indicators not only have to be relevant, but also have to be measurable, data has to be available (or retrieved with a reasonable effort/cost), and of good quality. At the same time a threshold for 'acceptance' has to be defined. The questionnaire method seems to be an adequate assessment tool especially for indicators in which the threshold is given by the compliance with national legislation and standards. Indicators used in the Ghanaian process fall into this category. Nevertheless, the parallel use of other methods, in particular direct observations and consultation of documents incorporating relevant quantitative and qualitative information provided by the companies or by governmental organisations, can provide a more objective base to the conclusions, and improve their reliability.

For the study in Ghana we decided to use a set of three questionnaires developed and field tested by Alfter (1999) in Zimbabwe: for the company management, for forest workers' representatives, and for the wood workers. The questionnaires also account for the different backgrounds of the interviewees and for different information levels. In defining the questionnaire the factual questions are privileged in order to eliminate as much as possible the answers biased by interviewee's subjectivity. In the same way, closed form questions were used for a majority of the cases. When needed, complementary questions allow the interviewer to obtain further precision on an issue.

Each type of questionnaire has its own specificity related to the targeted interviewees. The three questionnaires, of more than 100 questions each, nevertheless cover the same subjects. The questionnaires are structured in six sections:

1. Personal questions;
2. Compliance with ILO conventions;
3. Additional questions related to the working conditions;
4. Employment policy of the company;

5. Representation of the workers by trade unions; and
6. Questions related to forest certification.

An important section of the questionnaires is guided by the Conventions of the International Labour Organisation (ILO). The conventions adopted by ILO are taken as a benchmark against which national situations can be evaluated. In formulating the other sets of questions particular attention was paid to the processes currently developed for forest certification especially when the latter include principles, criteria and indicators related to the working conditions of the forest workers. It is widely acknowledged that sustainable forestry must include ecological, economic and social elements. Despite this, forest and wood workers' issues are often neglected or poorly developed (Bowling 2000).

4. Results and Discussion

4.1 The visit program

The visit in Ghana took place between the 22nd of August and the 11th of September 1999. TWU assured an excellent logistical support. We were able to visit 12 timber companies from five regions, and have a large number of interviews in nine of them. The visited companies are: Birim Woods (Central Region), Ghana Primewood Products Ltd. (Western Region), Du Paul Wood Treatment Ltd (Western Region), Samartex (Western Region), Swiss Lumber (Western Region), Oti Yeboah Company (Brong-Ahafo Region), Mim Timber Company (Brong-Ahafo Region), Scanstyle (Brong-Ahafo Region), Lumber Log Limited (Ashante Region), Prima Woods (Ashante Region), Furnart (Greater Accra Region), Drassaco Furniture Co. Ltd (Greater Accra Region). We also met the representatives of the National Sawyers Association, which is affiliated to TWU and represents the so-called informal sector, The National Women's Committee of the TWU and the TWU Committee for Forest Certification. We also met two representatives of the National Forest Certification Committee at the Ministry of Land and Forests.

In our programme we focused on SAMARTEX, one of the biggest, if not the biggest Ghanaian timber company, in terms of workforce, forest area, output, and exports. This choice was also motivated by company's interest in certification and the fact that the first field-test of the Ghanaian certification scheme was scheduled to take place (in autumn 1999) at SAMARTEX. At SAMARTEX we had the possibility to perform 16 interviews with workers, including with workers from the forest department and women, as well as with four trade union representatives.

During our visit, we performed a large number of interviews, with all three target groups (company representatives, union representatives, and workers). Usually we were received by a senior manager or by the personnel manager. Discussions were open and cordial. We made it clear from the very beginning that the objective of our visit was not to certify their company, but to make a study on how specific aspects of certification (i.e. assessment of criteria and indicators related to workers' rights) should be tackled. Several managers shared with us their views concerning the certification process. Management, especially senior management, is aware of the certification issue and follows closely the developments at the national and international level. Most of the visited companies, especially those that export a large share of their production, seem willing to enrol, either in the national, or if that fails, into an international scheme (e.g. Swiss Lumber looks at the FSC scheme). Several companies (e.g. Prima Woods, Samartex, Swiss Lumber), are actively seeking certification, and seem confident that they will obtain a price

premium and increased market access. However, they are concerned about its possible costs, especially that of the forest management auditing, and by the uncertainties associated with the certification issue. The managers we met widely share the perception that the national legislation is already very tight, and thus little additional costs would be necessary to improve the forest management and track the chain-of-custody. Managers in general, and personnel managers in particular, agreed that social concerns, especially workers' rights, are legitimate and should be accounted for in the certification process.

In all the companies we visited, we could count on the active support of local union representatives. Discussions with union representatives were fruitful and open. Almost all the representatives we met were well aware of what workers' rights were and the actual situation of workers in the company. In our opinion the assessment of indicators should heavily rely on in-depth discussion with them. In every company we visited there are at least two union representatives (the branch secretary and chairman). We tested both individual and group interviews. Individual interviews would maybe allow freer exposition of issues and problems, and cross-checking for consistency. Our experience suggests that performing a group interview led to clarification of questions and more accurate responses. We noted that the individuals maintained different responses when a disagreement on the essence of the answer, and not a problem of understanding, occurred.

As a rule we were guaranteed unrestricted access to workers, although on some occasions the choice was influenced by their availability during working hours. The atmosphere during the interviews was good, we did not feel that the interviewees feared unwanted repercussions from the management as a consequence of these interviews. We cannot assert with confidence to what extent the presence of national and local union leaders (sometimes shop stewards) influenced their answers. On some occasions we had the impression that the responses we had were intended to please union representatives and us. But as a rule workers did not avoid bringing forward their opinions, even when they obviously displeased the union representative. It is our opinion that in the Ghanaian society in general, and in the companies we visited in particular, freedom of expression is guaranteed. However, it is possible that interviewees (workers and worker representatives) could censor themselves if they think that disclosing certain aspects could unfavourably affect the company and thus their job prospects.

4.2 The questionnaires

The questionnaires we used were elaborated with the aim of formulating universal criteria for the assessment of the working conditions of forest workers. The questionnaires were tested during a previous study in Zimbabwe (Alfter 1999). As a consequence they are broader in scope than our main objective, i.e. the assessment of workers' rights indicators for the Ghanaian certification process.

Several interviewees were surprised by the comprehensiveness of the questionnaire and commented that the social objectives of the certification process seem much broader than they previously thought. Other interviewees, who knew the certification process better, sometimes made the accusation that there was a lack of focus in the interview.

The intended universal character of the questionnaires also means that the questions are not 'customised' for the legal and social framework that applies in Ghana. In particular, they do not include explicit reference to laws that are fundamental for every actor we met (e.g. Workman's Compensation Act, Industrial Relations Act). The Collective Agreement issue, its specific clauses that are essential in the Ghanaian context, are also only indirectly tackled. The constraint of this generality is something many interviewees had a difficult time coping with. Very often they needed a 'translation' in their local reference system.

We believe that the questionnaire should include explicit reference to the relevant national legislation and collective agreements especially as certification is a national process and national standards form the basis for the Ghanaian certification process. The questions should be framed in such a way that they test compliance with critical aspects of the national framework (e.g. the mechanism for conflict resolution). The assessment in an international perspective can be done by directly comparing the texts of the laws.

In order to facilitate the assessment of indicators we believe that the set of questions should more explicitly emphasise the collective agreement, as well as its availability and knowledge. The latter effectively embeds the legal framework and constitutes a reference document for the workers' situation.

The intrinsic length of the questionnaire associated with the widespread difficulties in understanding the wording of many of the questions meant that we had to spend a long time filling-in the questionnaires. A full questionnaire took as much as two hours to complete. This reduced the number of people who responded. Very often we had severe time limitations, also associated to travel times, which are usually long in Ghana. In these situations we preferred to apply a rather simplified questionnaire to a larger number of workers rather than perform only one interview.

ILO conventions are very poorly known, except by some senior trade union representatives. Anyhow, their name or the knowledge of their content seems less relevant than the questions that test the actual implementation of their main standards (e.g. Minimum Age Convention).

In our opinion several questions should be grouped (e.g. those related to training or the mechanism of consultation between the stakeholders). This would considerably shorten the questionnaires. Other questions that are not relevant for the assessment of indicators should be eliminated altogether.

While allowing rather subtle consistency checking of the opinions expressed by the interviewed person, the perceived repetitions in a structured closed questionnaire were repeatedly reported as being disagreeable by the interviewees. The repetitions were even more difficult in interviews with workers, as we had to explain to them the nuances between the different questions. Even in this event we cannot be sure that they were well understood. It is our opinion that understanding and other problems (e.g. translation) largely overwhelm the possible benefits of this approach. We recommend that a part of the interview should be dedicated to the identification of sensitive issues using the unstructured, open, interview technique. The questionnaires should be simplified, radically as that addressed to workers, and their structure should follow more closely the indicators chosen within the certification process.

During the interviews with managers it appeared that the best source of information was usually the personnel manager, who is in charge in most companies of relations to workers (including safety issues). However, several important pieces of information can be reliably retrieved only from the accountant department and forest department. Given the importance of the interviews for obtaining the certificate, we believe that questionnaires with managers should not be anonymous, but instead they should sign them. Naturally, the interviewee should be allowed to check his responses before signing. We also believe that group interviews (and questionnaire filling) by managers should not be ruled out. On several occasions senior managers were willing to answer the questionnaire themselves, but needed, for specific questions, the assistance of their collaborators.

Similar considerations apply to workers' representatives. We believe that union representatives have to assume the responsibility and sign the questionnaires, after checking them. Group interviews should also be allowed. Possible opinion divergence should be documented.

Interviews with workers should remain individual and anonymous. In our opinion a minimum of three to four (small companies) to ten (big companies) is needed to have a fair evaluation.

We conclude this section by giving our assessment about what we obtained using the interview technique.

1. Managers:
   - Their point of view concerning the degree of fulfilment of worker rights related criteria and indicators;
   - Some data (very sparse) concerning quantitative indicators;
   - Indications about the availability of documents (records, files, reports) able to substantiate their claims and for having data for quantitative indicators; and
   - Their position concerning certification process (willingness to enrol).

2. Union representatives:
   - Their point of view concerning the degree of fulfilment of workers rights; evaluate the respect by management of collective agreement and national legislation;
   - Evaluate their knowledge about workers' rights and situation efficient as worker representatives); and
   - Identify sensitive issues.

3. Workers:
   - Get a glimpse of their personal situation (salary, accommodation etc.);
   - Assess the representativeness and efficiency of union leaders; and
   - Identify sensitive issues.

4.3 Indicators: assessment and fulfilment

In discussing the assessment of the indicators provided by the Ghanaian certification process we will make the distinction between:

1. Quantitative indicators: on the basis of available data, a number or a quantitative measure can be associated to the indicator. For these indicators compliance can be established by comparison with some specified threshold values, or on the basis of trends in the time series of indicator values.
2. Qualitative indicators: indicators for which only a verbal statement can be documented. For these indicators compliance with certification requirements can be established on the basis of the conformity with a set of (verbally) specified conditions.

In our opinion the workers' rights related indicators should be considered as qualitative indicators. We also propose, and believe that it conforms to the spirit of Ghanaian process, to set the indicator threshold at the level of compliance with the current Ghanaian legislation. In other words, what has to be assessed is 'does a given company apply the current relevant Ghanaian legislation?' The answer should be 'Yes' or 'No'.

It is difficult to use at this stage quantitative indicators, such as number of accidents, number of days off, or minimum wages in the Ghanaian certification process. As a rule management does not compile statistics such as those related to accidents, or may be reluctant to disclose them. However, the necessary documents (e.g. police reports, insurance files, accountancy files) on the basis of which they can be assessed is available at the personnel and accountancy services, and they can be compiled relatively easily if the management is willing to collaborate. Nevertheless, the union can also be much more active on this issue, and establish independent records of accidents; something the collective agreement encourages them to do.

An additional difficulty is to propose an acceptable threshold for verifiers such as the number of accidents and combine them in a single evaluation. In our opinion assessment should be made on the basis of (medium-term) trends rather than on threshold values. The compilation of these data was beyond the scope of our mission, but it seems important to start collecting these statistics in order to build up time series and, at some point in the future, to be able to assess trends. With some effort these time series could also be extended into the past.

The main results of this study concerning the respect of workers' rights are synthesised in the two tables below. In Table 1 we present the results of our assessment of the four indicators considered in the Ghanaian certification scheme. In Table 2 we present an assessment of other elements, which arguably are not directly tackled by the indicators, but which seem relevant to us in the context of certification and more broadly concerning workers' rights in Ghana. The purpose of the study is to assess a methodology for certification, and not to certify the visited companies. Therefore, in the table below the companies are not identified.

Table 1. Assessment of the certification indicators in the visited companies.

Company	Health & safety 6.8.2.11		Wages & benefits 6.8.2.12		Injury compensation 6.8.2.13		Dialogue & conflict resolution 6.8.2.14	
	Yes †	No	Yes	No	Yes	No	Yes	No
Company 1		x	x		x			x
Company 2		x	x		x		x	
Company 3		x	x		x		x	
Company 4	x		x		x		x	
Company 5	x		x		x		x	
Company 6		x	x		x		x	
Company 7		x	x		x		x	
Company 8		x	x		x		x	
Company 9	x		x		x		x	

† "Yes" means that the company complies with the standards needed for certification standard for the indicator; "No" means that the company does not comply with certification standard for the indicator

Table 2. Assessment of other relevant indicators in the visited companies.

Company	Right to organise †		Collective Agreement		Diffusion of Coll. Agreement		Gender discrimination*	
	Yes	No	Yes	No	Yes	No	Yes	No
Company 1	x		x			x		x
Company 2	x		x			x		x
Company 3	x		x			x		x
Company 4	x		x		x			x
Company 5	x		x			x		x
Company 6	x		x		x			x
Company 7	x		x			x	?**	?**
Company 8	x		x			x		x
Company 9	x		x		x			x

† Only one union (i.e. T.W.U.) is presently active in the timber sector
* Ghanaian standards; as discussed in the report, in the Ghanaian society as a whole gender equality is still a problem
** No female employees

The occupational health and safety issues (indicator 6.8.2.11) are some of the most critical aspects with respect to the certification requirements. Although, the safety equipment is reportedly inspected on a regular basis by a governmental agency, in most of the visited companies we found insufficient protective clothing and equipment, insufficient training and insufficient awareness of workers for these issues. We note that Ghana has not yet ratified the ILO 155 Convention on occupational health and safety. The situation was especially manifest in the bush, where virtually no protective equipment was used (for example, in chainsawing). We also consider that local branch unions do not pay sufficient attention to this problem. They should more actively pursue this issue in discussions with both the management and the union members.

In all the companies we visited the minimum wage was respected. The minimum wage negotiated within the framework of the collective agreement is above the national minimum wage. However this minimum wage is very low and is not sufficient for ensuring a decent standard of living. The other benefits also conform to national standards. We noted, however, that in some companies in the recent past there were conflicts concerning the payment of overtime and the attribution of allowances. These conflicts are now solved. They indicate that, due to the very hard living conditions, workers are extremely sensitive to the issue of salary and are willing to fight for their rights.

We can also appreciate that in virtually all the visited companies the indicator concerning the injuries and damages caused to human health is fulfilled. The Workman's Compensation Act is applied everywhere to the satisfaction of workers and their representatives. However, only in a very few cases did we find measures that go beyond those asked for by the national legislation. In some cases the employers offer a (one time) small sum of money.

The procedure for dialogue and conflict resolution exists in every company, as the collective agreement establishes. There are periodic contacts between the involved parties. In the vast majority of cases, unions are effective representatives of workers' problems and grievances. Nevertheless, in several cases unions and workers complained that insufficient attention was accorded to the problems they raised and that some of the measures that were agreed upon during meetings with management were short-lived.

In every company we visited a Collective Agreement (CA) was in use. Most companies used the agreement negotiated at the national level between the Ghana Timber Millers' Organisation (the employers' union) and TWU of TUC. Some companies (e.g. SAMARTEX, Swiss Lumber) had a special collective agreement negotiated between the management and the union. However, even in the latter case, the national agreement served as a benchmark especially concerning minimum wages. Collective Agreements are extremely important for maintaining and improving workers' rights in a difficult economic environment characterised by high unemployment rates and a disengagement of government from the economic sector (e.g. the divestiture/privatisation process). TWU should be praised for their ability to obtain good conditions in many areas, and should be encouraged to negotiate harder, especially concerning the minimum wage which is perceived by a vast majority of interviewed workers and trade union representatives as insufficient for decent living conditions.

The CA is a very good framework for defending workers' rights, and we believe that it should be put in the middle of the indicator assessment methodology in Ghana. In our opinion the observance of the CA implies that the workers' rights indicators for certification are fulfilled. Nevertheless, we noticed that many workers and even workers' representatives were not aware of all its contents. In fact, the CA was not provided to all workers, and only in a few instances it was made available at the department level.

We also believe that respect by the employer of the CA can be assessed using the interview technique. Questions like "Do you know the CA?" (Yes/No), "Is the CA applied, without exception, in the company?" (Yes/No; Can you justify?), "Do you know what are the clauses

with respect to safety measures?" (Yes/No; What are they?), can allow a fairly good evaluation. At the same time we believe that an improved knowledge of the CA would be a guarantee for a stricter respect of workers' rights. We noticed some present and recent infringements of the clauses of the CA Nevertheless, the legal framework allows workers and workers' unions to effectively defend their rights, which is something that they actually do, within the conflict resolution procedure. As mentioned before, workers sometimes resort to strikes, but in order to succeed in their claims the leadership of the union is needed.

In most of the aspects related to workers' conditions the CA has fairly good standards. As mentioned before, a notable exception is the minimum wage, which seems quite low with respect to other sectors. It is particularly difficult for someone who does not know the situation in detail to appreciate the different compensation and/or consolidation schemes (bonuses, allowances, free meals or accommodation). It turns out that in most situations the salary is close to the minimum wage as established by the CA. In its turn, the latter is quite close to the minimum salary at the national level (3300 cedis vs. 2900 cedis). This results in poor living conditions, but the requirements of the CA and national standards are respected. Clearly the living standard of workers and their families is quite low. Although above the minimum wage (but by a relatively small percentage), it allows only for the satisfaction of very basic needs (food and accommodation) of forest and wood workers and their families. The increase of wages is, by far, the most important and pressing grievance of workers and union representatives.

In the companies visited, virtually all of the workers were members of the union. A notable exception is the senior staff, but in some companies (e.g. SAMARTEX) the senior staff are also unionised. In accordance with the CA and national legislation (Industrial Relations Act 1965), dues to the union (2% of salary) are deducted from salaries and directed to TWU. The union fulfils its function as workers' representative. In most companies we visited TWU had a prominent role in the mechanisms of communication and conflict resolution between workers and management. Election procedures for union leaders are fair and democratic. The TWU is widely trusted by workers and generally does a very good work in defending workers' rights. The union manages to make the employers respect the CA. Freedom of association is guaranteed and in several economic sectors there are attempts to organise alternative trade unions, although the necessary conditions make this process a difficult one.

We can assert with a high degree of confidence that there is very little or no discrimination on ethnical, racial, religious, or political grounds. The gender issue is more sensitive. Despite adequate legal frameworks, in the Ghanaian society women do not yet have statuses equal to that of men. However, we did not find gross discrimination, and from our discussions it appears that the situation is evolving, albeit slowly, in the right direction. We did not find any special measures against discrimination in the companies visited, and we do not believe they are necessary, with the exception of those against gender discrimination.

5. Conclusions

During three weeks of fieldwork in Ghana we tested the social indicators for forest certification. We visited more than ten timber companies and had discussions with workers, their representatives, and representatives of management, as well as with members of the Ghanaian National Certification Committee. We were able to perform a significant number of interviews with the targeted groups: about 50 with workers, twelve with their representatives and nine with company representatives.

The main conclusion of this study is that the interview technique, complemented by direct observations and collection of relevant documents is effective in assessing the indicators

related to workers' rights, as they are formulated in the Ghana Forest Standard. Moreover, we consider that the selected indicators allow one to assess the criterion related to workers' rights. In our opinion, these indicators should be considered as qualitative. The respect of Ghanaian work and social legislation should be selected as the threshold for certification. The standing with respect to this threshold should be 'Yes' or 'No' ('Yes' means meets the national legislation, 'No' means does not meet national legislation).

Among the indicators, the first one (forest employers take care of forest related risks for workers) can be more amenable to quantitative assessment based on objective methods. Indicators related to accident and disease number, type and consequences can be assessed based on existing files and records, which can be found in the personnel and accountancy services. Data concerning training activities can also be collected and supplemented with information from interviews. As far as the protective gear is concerned, interviews and direct observation can complement accountancy documents. The difficulty with this quantitative measure is to establish and agree upon acceptable thresholds. Therefore, at least until necessary data are collected and time series are constructed, we recommend the use of qualitative indicators.

We recommend the adoption of the interview technique as a method to assess the fulfilment of indicators related to workers' rights. We advise closed form, structured questionnaires, with the questions being framed so they correspond as closely as possible to indicators. We also advise that the threshold of compliance with the Ghana certification scheme be clear. The closed questionnaire seems adequate for assessing indicators, as straight, clearly formulated, and reproducible answers have to be elicited from respondents. Subsidiary questions may concern possible justifications for not fulfilling some conditions, as well as the availability of supporting documents (what, where). We believe that the responsibility of the management should be engaged by asking them to check and sign the questionnaires.

It should be recognised that this method is less effective for unravelling sensitive issues or facts. Unstructured, individual, interviews may be more effective in detecting potential problems, or infringement of conditions necessary for certification. However, from an ethical point of view it seems fair to us to clearly state what the indicators are, and what the thresholds to obtain the certificate are. Along the same line, management should be offered the possibility to elaborate a common position, and that the answer to specific question should be offered by the person in charge of that area. In most companies we visited, there is no single person who can accurately answer all the aspects involved. Instead there should be at least three people: a very senior manager, the personnel manager, and the chief accountant.

The TWU of TUC, as the representative of workers, comprehends their rights and their actual conditions. Therefore, we recommend that certifiers consider TWU as a privileged partner in assessing workers' rights related indicators. A group formed by the branch chairman and secretary, as well as a regional or national officer would ensure a high quality input for the process. We recommend that the responsibility of union representatives should be engaged by asking them to check and sign the questionnaires.

Nevertheless, in order to enhance the credibility of the process, interviews with workers should be maintained. We believe that between four and ten interviews per company are needed to make an accurate assessment. For the latter we recommend a mixed approach. Firstly a shortlist of closed- form, simple questions touching the following aspects: salary, possession/knowledge of CA, safety equipment, accidents (and compensation), training, trust in union representatives. The aim of this list is to have a clear check that the workers' particular work conditions match the assertions of management and union representatives. The second part could be conducted as an open, unstructured, interview with the aim to detect potential problems, without needing to be factual and accurate. Interviews with workers should remain anonymous. Management should accept beforehand that any worker selected by the certification body should be allowed to

participate in such an interview. The accident files, or those documenting disciplinary measures, could serve to target some of the interviewees.

A procedure for conciliation of the potential conflicting opinions of management, trade unions, and indications from workers has still to be devised. On several occasions, we identified such disagreements (e.g. safety measures, overtime payment), but did not attempt to explore them further, in order to solve the contradictions. When available information does not allow the certifier to take a decision, we suggest a 'courtroom' format, in which parties can argue their case, and bring in new evidence, but the decision should belong to the certifier.

Finally, we have to recognise a potential flaw in the approach used during the study. We asserted that the main objective of the interviews with the workers should be to check the accuracy of the affirmations made by company and union representatives. Thus, in our interviews union representatives always accompanied us during the interviews. It may be argued that this does not correspond to the standards of an independent verification. Clearly, this will not be the case with the certifiers accredited by the Ghanaian Certification Board.

Direct observations (and photographs) which are also suitable, for example concerning safety measures, primary documents (records, files) as well as compilations and statistics concerning compensation schemes, safety measures, and so on, should be collected whenever possible.

We recommend that the questionnaires be simplified and focussed on the lines detailed in this report. The questionnaires we used were developed for a broader aim, and therefore, they contain several questions that are not directly relevant for the assessment of indicators.

In relation to the actual fulfillment of the indicators in the companies we visited, our results suggest the following:

1. The fulfillment of indicator 6.8.2.11 "Forest employers take care of forest-related health risks for workers".

   This indicator seems critical in most of the visited companies, and in particular in forest activities. Protective equipment and training do not correspond, in the author's opinion, to international norms, to Ghanaian national standards, and with the collective agreement. Workers and their representatives are mostly concerned by the problem of wages and other benefits and give less importance to issues related to safety. Therefore, we consider that IFBWW should recommend the TWU to emphasise its action on safety issues by:
   - Increasing the awareness of workers and workers representatives about work safety related issues; press management to improve work safety.
   - Strengthening the activity of the Health and Safety Committees. The issue of safety equipment and safety training should be raised in discussions with the management, and pressure should be exerted in order to improve safety measures (training, equipment, inspection).
   - Collecting and working on accident and sickness data (art. 14.13 and 14.14 of the CA).
   - Organising workshops and seminars on safety measures for branch union representatives and workers.

2. Indicator 6.8.2.12 "Wages and other benefits conform to national standards".

   This indicator is fulfilled in the visited companies. Although arguably very low (minimum wage about 1.25 US $/day), and almost unanimously considered by workers and their representatives as insufficient to ensure a decent living standard for them and their families, they are above the national standard (about US$1.10/day). Although the difficult socio-economical context they have to cope with is recognised, IFBWW should encourage the TWU to negotiate harder for better wages within the framework of the Collective Agreement. Other strategic sectors (e.g. the gold mines) have apparently managed to obtain better conditions. Top national officials, who directly participate at the negotiating

process for the CA, could be offered assistance from the IFBWW in the form of short courses or consultations of a negotiation expert.

3. Indicator 6.8.2.13 “Injuries and damages caused to human health are compensated in a fair, prompt and adequate manner”.

   This indicator is fulfilled in the visited companies.

4. Indicator 6.8.2.14 “There is a procedure for dialogue and conflict resolution between management and other employees”.

   This indicator is generally respected. However, in several companies workers and their representatives complained that the dialogue is not always effective, and that measures are sometimes insufficient or short-lived.

We also believe that two other points should stay in the attention of TWU:

5. Improve the availability and knowledge of the Collective Agreement. Although the employer’s obligation is to give a copy of the CA to each employee (art 3a. of the CA between Ghana Timber Millers Organisation and Timber and Woodworkers’ Union of TUC) this is not respected. The employers claim that this is too expensive.

6. Although progress has been made in this direction, the issue of gender equality in Ghana, should stay as a priority for both TWU and IFBWW. TWU should continue to organise seminars on gender awareness and, possibly in collaboration with IFBWW organise a ‘pilot’ day care centre project.

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Toward the Assessment of Forest Biodiversity at the Scale of Forest Management Units – a European Landscape Perspective

Per Angelstam[1,2], *Monika Breuss*[3], *Grzegorz Mikusinski*[1,2]

[1] Swedish University of Agricultural Sciences, Department of Conservation Biology, Grimsö Wildlife Research Station, Riddarhyttan, Sweden
[2] Department of Natural Sciences, University of Örebro, Örebro, Sweden
[3] Department of Wildlife Biology and Game Management, University of Agricultural Sciences, Wien, Austria

Abstract

The aim of this paper is to discuss the conceptual and practical challenges in forest biodiversity assessment that we face when moving from the stand scale and including also the scale of a whole forest management unit, which we consider to be synonymous with the landscape scale. To conserve forest biodiversity is a challenge for sustainable forestry, but also for other forms of land use. The reason is that many of the components of forest biodiversity have been rescued, or even created, by traditional management methods that were practised in the old cultural landscape. To assess status and progress in biodiversity management, ideally all the components of biodiversity (species, habitats and genes as well as functions) should be considered at multiple scales ranging from a single tree, to the forest management unit and up to landscapes in regions. This complexity is partly in conflict with the practical assessment and successful communication of the status and trends of biodiversity to different stakeholder groups. Being easy to communicate, the species component of biodiversity is, therefore, of particular interest. For example, a rigorous test should be made of the idea that specialised species with large area requirements, and that are well known to managers, could be used as 'umbrellas' that can also be used to protect other less demanding species in the different forest types. The species perspective is also useful to mitigate problems of habitat loss, i.e. to assure functional habitat connectivity. Finally, to achieve integration among relevant disciplines as well as links from policy to practice, we argue for the landscape concept as a platform for both the management and measurement of forest biodiversity. To ensure sufficiently rapid progress in the assessment, management and restoration of forest biodiversity, three questions are identified as particularly important. First, quantitative benchmarks have to exist, against which biodiversity measurements can be

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compared to assess the progress in forest biodiversity restoration. This is particularly important because time lags in the response of species populations to habitat loss overestimate the viability of species. Second, a clear vision of the authentic (both natural and cultural) composition and structure of the forest ecosystem that species have evolved with, or adapted to, must be at hand. This can be sought by studying biodiversity in both altered landscapes and reference ecosystems in the steep gradients of land use history found in many parts of Europe. Third, in developing biodiversity measurements the extent to which existing management methods harmonise with the evolutionary past should be understood.

Keywords: biodiversity, assessment, forest management unit, habitat loss, extinction threshold, landscape, umbrella species, communication, reference ecosystems, Europe

Introduction

To maintain biological diversity is one of the challenges of sustainable forestry. Presently there is a strong movement in Europe and North America towards a multiple-use policy with less emphasis on timber production, and more on non-timber values (e.g. Liaison Unit in Lisbon 1998). Thus, the role of forests should no longer be only to provide an important sustainable source of wood, which captures carbon dioxide. Forests should also maintain the vitality and health of forests, the production of non-wood resources, biological diversity, and protective functions as well as support socio-economic development. Hence, only about a decade after the term biodiversity was coined (Wilson 1988), the maintenance and enhancement of biodiversity have become recognised as central aspects of sustainable forest management (e.g. Hunter 1999).

Traditional West European forest management practices have focussed on timber production. As a result, monospecific, even-aged stands, mainly composed of coniferous tree species were usually produced (Peterken 1996; Angelstam and Pettersson 1997; Esseen et al. 1997). Hence, a whole range of forest qualities being present in naturally dynamic forests (e.g. old trees and stands, dead wood, stands with mixed tree species, large forest areas) have declined (Hannah et al. 1995; Angelstam 1996; Peterken 1996; Scherzinger 1996; Tucker and Evans 1997; Grabherr et al. 1998; Uliczka and Angelstam 1999). As a consequence, many forest specialist species have disappeared from large parts of Europe, and many others are presently endangered in remnants of suitable habitat (Stanners and Bourdeau 1995; Hagemeijer and Blair 1997; Mikusinski and Angelstam 1998).

A major challenge is to maintain biodiversity not only locally in the short term, but also within the whole forest management unit in the long term. Therefore, ensuring success with respect to the biodiversity criterion of sustainable forestry is a grand commitment. To alleviate the success of new initiatives and eventually reaching the long-term goal of maintaining biodiversity in Europe, it is essential that appropriate knowledge exists, and that the transfer of experiences between scientists and practical management is satisfactory. However, trying to translate the policies stating that biodiversity should be maintained into operational goals and ways to monitor progress is a critical issue, especially when multiple scales need to be considered (Noss et al. 1997; Bunnell and Johnson 1998; Vähänen et al. 1998).

The aim of this paper is to present conceptual and practical challenges in forest biodiversity assessment that we face when moving from the stand scale and include also the scale of a whole forest management unit, which we consider to be synonymous with the landscape scale. Due to the multitude of stakeholders involved, and the consequent need to simplify complex concepts we first define what is meant by forest biodiversity across spatial scales. We then discuss the need for continuous monitoring and communication as well as how

species can be used as measurement surrogates. We argue that the landscape concept used by landscape ecologists, and recent advances in conservation biology, can be linked to the landscape perspective of managers and owners on the one hand, and to the policy makers on the other. In doing that we believe that the forest biodiversity concept can be addressed in operational terms, considering both natural and human factors as creators of habitat, and acknowledging the contribution of new nature-friendly land management methods.

Measuring Biodiversity

What is forest biodiversity?

The biodiversity concept was coined to create a public awareness about "the urgent warning that we are rapidly altering and destroying the environments that have fostered the diversity of life forms for more than a billion years" (Wilson 1988). The accumulation of data on deforestation and species extinction made the biodiversity problem evident for a broader public by 1980 and has since then gradually picked up momentum. After about 10 years, the maintenance of biodiversity became accepted as one of the main global environmental problems along with global climate change.

Biological diversity has been defined and re-defined by many actors and eventually become a buzzword (Kaennel 1998). Species, genes, habitats and functions all remain key parts of the biodiversity concept (Heywood 1995; Harper and Hawksworth 1995), even if different stakeholders tend to stress different aspects. Nevertheless, this definition is not directly and operationally useful at the scale of the forest management unit. In Europe, the need to use biodiversity indicators in forest monitoring programmes has now been formalised by the Ministerial Conference on the Protection of Forests in Europe (Liaison Unit in Lisbon 1998). For practical work in planning and management, the maintenance of forest biodiversity and the sustainable use of forest resources require knowledge about how to assess the viability of populations of different species, forest habitat quality and important system functions (e.g. Wildlife Society 1993).

To define a forest from a forest biodiversity standpoint is complicated, especially when the history of land use is long. The fact that Europe shows such a large variation among its forest types, being both natural and created by man, does not make this easier. A simple and practical definition of forest that takes forest biodiversity into account would be "an assemblage of trees that hosts a variety of species found in the authentic forest of the region" (Angelstam 1999). By 'authentic' we mean landscapes with forest or woodlands, including ancient cultural landscapes, as they appeared before the intensive changes that commenced at the beginning of the industrial and agricultural revolutions (e.g. Butlin and Dodgson 1998). This definition covers a wide range of environments where components of natural forests are present, ranging from woodland pastures to the naturally dynamic forest in a large wilderness area (Peterken 1996; Kirby and Watkins 1998; Muir 2000). It should, however, be noted that the difficulties in finding suitable reference areas to understand the composition, structure and function of such authentic system becomes increasingly difficult the longer the land use history is.

Spatial and temporal scales

A tree, a characteristic habitat type as well as a landscape type can be viewed as patches at some scale. Whether we consider patchiness important or not, often depends on our

prejudices and spatial resolution when mapping patches. From a biodiversity point-of-view patchiness is also specific to a particular component. As an example different species experience landscape mosaics differently depending on the resources that they need. This means that patches may have to be defined differently depending on the topic in focus. Hence, rather than as juxtapositions of discrete forest types, patches should to some extent be seen as the interaction of continuous variables that vary continuously through space and time.

To make sense in practical management, all kinds of patchiness must be given a scale. Depending on the size and/or area requirements of the animal, the plant or the process studied, the hierarchical structure of territories, populations, metapopulations and demes may be shifted up or down the geographical scale (e.g. Allen and Hoekstra 1992). Because of these aspects of scale, there is often confusion about what is large and what is small among scientists working with different organism groups (e.g. Wiens 1989). What is a large geographical area to plants and insects is usually small to vertebrates. The patch structure of a given environment also changes through time due to fire, wind and changing land use (e.g. Picket and White 1985). Therefore, the responses of individuals and populations to patchiness are dynamic. Consequently, community organisation and processes must be defined both with respect to space and time so that it can be implemented in practical management.

To account for the habitat components in a landscape which affect populations, management must be made at different geographical scales. For forest the following division is useful:

- the compositional and structural details within a habitat unit (e.g. at the scale of a tree or a log in a small forest stand);
- the composition and structure which are characteristic at the level of the habitat unit (e.g. a forest stand);
- the composition and structure at the scale of forest management units in a landscape.

Traditionally, land use managers have mainly been concerned with criteria at the intermediate level of landscape units (i.e. stands). Retention of live and dead trees during clear-cutting, and the efforts to create buffer strips along creeks represent novel considerations to improve compositional and structural details that promote the ecological diversity. Similarly, new methods for ecological forest planning aim at maintaining or restoring structures at the landscape level (e.g. Angelstam and Pettersson 1997).

In land use management there is considerable variation in the range of spatial and temporal perspectives in terms of forest biodiversity. Traditional forest management focussed on timber production and operated almost exclusively at the stand level while planners think in much broader scales. Therefore, all scales are relevant also from a management perspective (Voller and Harrison 1998) (Table 1):

Table 1. As illustrated in this table different types of managers operate over different ranges of spatial scales. To understand the effects of management on biodiversity, it is therefore important to aggregate the consequences of management across different spatial scales.

	Spatial scale		
Type of manager	Trees in stands	Stands in landscapes	Landscapes in regions
Private owner	x	x	
Forest company	x	x	x
Public owner		x	x
Regional planner			x

A matrix of forest biodiversity measurements

Assessment and management of biodiversity requires that its different components are defined as clearly as possible, and that the factors underlying the loss can be identified. Harper and Hawksworth (1995) stressed that the full definition of biodiversity must be kept in mind, and proposed the adjectives genetic, organismal and ecological to describe the three components of biodiversity. Moreover, a number of important processes/functions, which affect forest composition and structure (e.g. fire, flooding, browsing, fungal and insect infestation) should be considered (e.g. Noss 1990; Angelstam 1998a,b; Angelstam et al. 2000a; Gossow 1996).

In land use management there is considerable variation in the range of spatial and temporal perspectives in terms of planning and management. While forest management is usually focussed on timber production at the stand level, regional planners work at the scale of landscapes in regions. In a broad sense forest environments can thus be divided into three scales:

- trees allocated to different species, age, size and spacing classes make up patches/stands of a particular forest type;
- stands with different tree species composition, tree age and size structure, and vegetation layering make up landscapes;
- landscapes with different amounts of forest cover and stand composition make up forest regions.

In Table 2 we have compiled examples of the different ways in which we have found forest managers in two forest-dominated countries (Sweden and Austria) working with the different components of biodiversity across spatial scales (Angelstam et al. 2000a).

Table 2. Components of biodiversity that are presently being considered in practical forest and land management in Sweden and Austria (from Angelstam et al. 2000a).

	Tree	Stand	Landscape
Species	occurrence of insects and bracket fungi as indicators of forests with high conservation value	occurrence of lichens and smaller resident birds as indicators of forests with high conservation value	occurrence of woodpeckers and grouse as indicators of forests with high conservation value
Habitat	tree and shrub species and age composition, vertical and horizontal cover, retention of hole trees, standing and lying dead wood	ground vegetation, tree and shrub species composition and age class	age class and tree species composition, patch size distribution, road network
Processes	snag engineering by cutting high stumps or blasting	re-introduction of fire disturbance	browsing and bark peeling damages by large herbivores
Genes	selection of fast-growing tree provenances	not considered	not considered

Monitoring and Communication

The monitoring loop

A vital part of the implementation of policy is the evaluation of the extent to which the real world changes in the desired direction. The aim of monitoring is to apply short-term steering to attain long-term goals. To be effective, monitoring of biological systems must have a sound scientific basis, be diagnostic and help understand the system, allow assessment of the stated policy objectives and, finally, include feed-back to the policy process and/or management to enable mid-course corrections. Maintaining simultaneous focus on several scales in management is difficult in itself. Moreover, the gradual changes in the amount of different age classes, patch size and habitat connectivity take time. While these measures certainly may go in the right direction, it remains largely unclear whether or not both the rate and extent of change is sufficient to maintain viable populations of all the naturally occurring species.

Monitoring of biodiversity measurements (i.e. indicators) should be viewed as an iterative process where the information flow should be secured; therefore monitoring is a vital component in Adaptive Management (e.g. Walters 1986). Adaptive Management can briefly be described as 'learning by doing' and represents an evolution from best current data-approaches to a sophisticated monitoring and modifying approach (e.g. Bunnell and Johnson 1998). This method has been applied to management of various natural resources, but has so far not been applied in Europe. The advantage of Adaptive Management is that it involves a diversity of stakeholders from scientists, practitioners and different interest groups. Although difficult, in this way the gap between science and policy can be reduced, and institutions with incentives for active management and conservation created. Thus, unnecessary tension in management and conservation can be removed. Adaptive Management is designed to improve on trial-and-error learning and integrate uncertainty into management strategies. It emphasises practices that confer resilience in the sense of improving the capacity of an ecosystem to absorb disturbance and maintain opportunity for renewal, reorganisation and recovery after disturbance. By responding to and managing feedback from ecosystems, instead of blocking them out, Adaptive Management seeks to avoid exceeding ecological thresholds at scales that threaten the existence of social and economic activities. Adaptive Management is an iterative process, which includes the following steps:

1. Define criterion;
2. Derive guideline;
3. Find indicator; and
4. Monitor, and then back to 2! (see also Table 3).

Table 3. Steps in conservation planning and their definition.

Policy	Legal basis for criteria to be met
Data	Conservation planning requires data on the components to be planned; e.g. forest types, ownership pattern, species
Goals	Definition of quantitative target to be met both short-term and long-term
Gap analysis	Using spatial and temporal considerations gaps in the existing network is made both with respect to representativeness and to extent
Selection	Identification of sets of areas that will fill the gaps
Implementation	Formal set-aside and/or management of the conservation areas
Monitoring	Controlling the conservation areas continue to contribute to the policy

Umbrella species as communication tools

To assess status and progress in biodiversity management, ideally all the components of biodiversity (species, habitats and genes as well as functions) should be considered at multiple scales ranging from a single tree, to the forest management unit and up to landscapes in regions. This complexity is partly in conflict with assessment and successful communication of the status and trends of biodiversity to different stakeholder groups. Being easy to communicate, the species component of biodiversity is, therefore, of particular interest.

Among the different types of surrogate species used in conservation planning, umbrella species (*sensu* Simberloff 1998; Caro and O'Doherty 1999) appear particularly interesting as a tool to alleviate communication among stakeholders about forest biodiversity. An umbrella species is a species, the presence of which is associated with a co-occurrence of many other species of that habitat. Because of the diversity in forest dynamics and forest types, in most forest landscapes a suite of umbrella species would be required. The selection of umbrella species should hence be based on detailed knowledge about the quantitative requirements of the most area demanding species for each forest environment. Research on several specialised species with large area requirements that are found in different forest environments support the umbrella species concept. For example, for capercaillie (*Tetrao urogallus)* (P. Helle personal communication), white-backed woodpecker (*Dendrocopos leucotos)*, three-toed woodpecker *(Picoides tridactylus)* (Martikainen et al. 1998; Mikusinski et al. 2001), as well as the long-tailed tit (*Aegithalus caudatus)* (Jansson 1998) it has been shown that a variety of other species co-occur in the respective forest types. However, before employing the concept of umbrella species suites it is essential to manage for the habitat of the umbrella species and not for the species itself, and to test whether or not other components of biodiversity are associated with the umbrella species.

The Landscape Concept as a Platform

Functional habitat connectivity

The concept of functional connectivity includes both the spatial configuration of habitats, and the life-history traits of species' populations (e.g. Forman 1995; Bennett 1998). Sufficient spatial and temporal connectivity of stands of a particular forest type, or combination of types, is a crucial prerequisite for the occurrence of viable populations of different species that specialise in that forest type (e.g. Tilman and Kareiva 1997; Jansson and Angelstam 1999). However, species differ greatly not only with respect to the kinds of forest environments that they require, but also in relation to the size of those environments. Securing long-term population viability of umbrella species such as specialised larger birds and large mammalian predators with large area requirements will underline the need for a network of suitable forest patches at the scale of landscapes in regions (Gossow 1988; Mikusinski and Angelstam 1998; Storch 1999). Using several species representing different forest environments is an approach that is likely to ensure that more aspects of the landscape are covered (see Lambeck 1997; Angelstam 1998a,b).

Securing integration among disciplines

In most European languages the word for 'landscape' is related to the act of domesticating the original nature to the benefit of human welfare. In the sciences of biology and geography the landscape is a geographically distinct area where abiotic and biotic conditions interact with and

set limits to the historical and cultural dimensions of human use. The composition of biodiversity of a given landscape or community depends on several groups of factors spanning the gradient from effects of abiotic and biotic factors to historical/political factors (Brouwer et al. 1991; Turner et al. 1990; Angelstam 1997; Fraser Hart 1998). This broad pattern is obvious at all scales ranging from the global and regional scale, to the scale of a few hundred square meters by practical adaptation of forest management to the site type. Therefore, for the development of a scientific basis for the maintenance and restoration of biodiversity in practice, it is required that sufficiently broad sets of scientific disciplines are included.

Abiotic factors (topography, soils, bedrock and local climate) determine the biotic conditions in terms of the past long-term changes in the vegetation types and the related plant, animal and fungal communities (e.g. Ellenberg 1996). Superimposed on these natural factors, there are different types of anthropogenic change. These range from the slow and gradual transformation of landscapes by the introduction and development of old-fashioned forestry and agriculture (Birks et al. 1988; Berglund 1991; Schiess and Schiess-Bühler 1997), to the more recent effects on landscapes caused by intensified land use management, pollution and apparent global warming.

The landscape as a link from policy to practice

Ideally, the different scales from trees in stands to landscapes in regions need to be integrated both by top-down planning and bottom-up integration of different management efforts. A policy can be viewed as a definition of a vision for subsequent successful implementation. However, the vision should be operationalised. Conservation planning for the establishment of representative networks of protected areas is an example of an important type of top-down planning (Noss et al. 1997; Prendergast et al. 1999; Margules and Pressey 2000; Angelstam and Andersson 2001).

However, this should be complemented by bottom-up integration. Forest certification is one tentative example. From 1990 forest certification was initiated by environmental organisations to promote the development of sustainable forest management, as well as to provide a better market for products that meet certain standards. In an analysis of the development of forest certification programs in Indonesia, Canada and Sweden, Elliott (1999) concluded that certification can be best understood as a policy instrument, which promotes and facilitates learning among actors, both during the development and implementation of standards. Hence, certification provides direct incentives for improved forest management at the scale of the forest management unit. Moreover, the consensus-building among actors such as NGOs, forest owners, indigenous people and government who have traditionally been in conflict with each other, can be significant. It should, however, be stressed that successful conservation of biodiversity takes more than meeting the present certification standards, which so far are the results of negotiations between stakeholders with very different views, rather than based on scientifically based quantitative knowledge of what biodiversity maintenance requires.

Summarising, to maintain forest biodiversity it is essential that we take a multi-perspective view, such as provided by the landscape concept. The landscape scale thus provides a compromise between top-down and bottom-up approaches. There are several parallel arguments for a landscape perspective:

- it implies a multi-disciplinary view including both the natural and cultural aspects of forest biodiversity;
- it stresses that individuals of many species need large areas and that the maintenance of viable populations all species long-term maintain requires large areas;

- it argues in favour of retained patch dynamics of different successional stages including old-growth requiring management and conservation over large areas.

Towards Successful Management of Forest Biodiversity in Europe

Most of the forests of Europe have been impacted by a variety of changes and the present landscapes have diverged greatly from both the natural patterns and processes of the original forest landscapes as well as from the cultural landscapes with soft transitions between grasslands and ancient woodlands. The difference between the forest components in these two landscape types is less than one might expect. Several properties, important for the maintenance of forest biodiversity, are now absent or uncommon where the history of modern management methods is long. These include old-growth forests and old large trees, a diversified tree species composition, a diverse range of structural forest components, dead standing and fallen trees, and balanced natural processes (e.g. browsing, predation, nutrient supply).

In particular, biodiversity management involves creating structurally diverse stands with native species, arranging the juxtaposition of stands to preserve the individual species as well as species interactions, and restoring connectivity among different habitat types and properties in forest landscapes. These requirements will be related to activities in several steps:

- selection of the natural forests that should be protected – in most regions with a long forest history this means all natural or near-natural forests;
- conservation of the semi-natural forests;
- improvement of managed forests; and
- re-creation where certain habitat components are lacking.

How much habitat is enough?

Both theoretical models and empirical data suggest that there are thresholds in the response of populations to habitat loss at the scale of landscapes (e.g. Tilman and Kareiva 1997; With et al. 1997; Andrén 1994; Fahrig 2001). As the proportion of a given habitat declines, the chances of a successful colonisation of the remaining fragments decrease stepwise. The effects of fragmentation are thus not linear. For example, Franklin and Forman (1987) modelled landscape dynamics and found that when 70% of the original habitat remained, the first patches became isolated. As fragmentation proceeds, more patches become isolated, and when 30% of the original habitat is left, the entire original habitat exists in fragments. Continued habitat loss leads to an exponential increase in the distance between patches (Gustafson and Parker 1992; Andrén 1994).

As shown in a review of the effects of habitat isolation on species richness at the landscape level by Andrén (1994), the negative effects of reduced patch size and isolation tended not to occur until less than 20–30% of the suitable habitat remained. This level of habitat loss thus appears critical for the long-term maintenance of viable populations, at least for the vertebrates studied. When 5–10% of the original habitat is left, species usually have become locally extinct. Based on these results, a preliminary answer to the question of how much habitat loss is acceptable without losing the most area demanding specialist species falls in the range of 10–30% of the original habitat coverage. However, as stressed by Fahrig (2001) there is an urgent need to find empirical data that explore the variation in threshold values for the effects of habitat loss on populations in different habitats and types of landscape mosaics.

Urgency and extinction debt

The thresholds in extinction imply that when the habitat patch network is degraded by destruction of some of the habitat patches, the network may no longer be capable of supporting a viable population of the focal species. However, extinction of a local population is not immediate and the exact timing can be viewed as a stochastic process. For example, two consecutive years with exceptionally unfavourable weather conditions or other such factors might lead to extinction. The time period during which a species persists after habitat destruction is called the time delay. Theoretical considerations show that the time delay is greatest for species for which the degraded environment is near the threshold for persistence (Hanski 1999, 2000). On the contrary, a species for which the quality of the current environment is far too poor is predicted to become extinct rather quickly. Time delay depends naturally also on some species-specific factors such as the average lifetime of individuals.

The number of species that are expected to become extinct due to past adverse environmental changes is called extinction debt (Hanski 2000). Compared with what we can actually observe, this time delay makes us underestimate the risk of extinction. The term extinction debt describes this time delay. After deterioration of a habitat patch network there may be a number of species, which will inevitably become extinct although they have not yet done so. Before the extinction debt is paid by actual extinctions, the relative proportion of rare species will increase. It should also be noted, that the inertia in the event that attempts to restore connectivity takes an even longer time (Tilman and Kareiva 1997).

Land use history gradients and reference ecosystems

The geopolitical location of European countries has had profound effects on the amount of deforestation and intensity of landscape transformation characterising the different countries (Chirot 1989; Gunst 1989; Butlin and Dodgson 1998). The most important driving force of further change, the Industrial Revolution, started in Western Europe in the 18th century and spread gradually to the peripheral regions. The term Industrial Revolution describes the rapid transition from an agrarian society to an industrial society (first occurring in the UK where the process started during the period 1760–1840), but also the transition process in general (Barraclough 1978). This spurred a rapid infra-structural development with mechanised factories, urbanisation and efficient transportation on canals and regulated rivers, roads and railroads. These changes exerted a strong and rapid change in the amount of impact on a landscape, which previously had been exposed only to slow rates of change during many previous centuries or millennia. The same development as in the UK later took place in France, Belgium and Germany at the beginning of the 19th century and later in other parts of Europe (see Mikusinski and Angelstam 1998).

Hence, although Europe covers a relatively small area in a global perspective, it has a broad spectrum of landscape histories, which are specific to a particular country or region (Angelstam et al. 1997). Therefore, taking into account differences in the degree of human impact among the different European landscapes, the proportion of the original forest biodiversity that remains tends to increase in Europe from the economic centre to the periphery, i.e. often from West to East (Mikusinski and Angelstam 1998; Angelstam et al. 2000b; Yaroshenko et al. 2001).

Such gradients in biodiversity are important tools for understanding the human footprint on nature, and to learn about the authentic biodiversity in reference ecosystems. Such insights and knowledge can then be applied for the maintenance and restoration of biodiversity in heavily impacted regions (e.g. Egan and Howell 2001). Two clear examples for employing this approach are the Baltic Sea region (Angelstam et al. 1997) and the old Habsburg Empire (Good 1994).

The Baltic drainage basin is surrounded by all the three major forest regions found in Central and Northern Europe. These range from the broadleaved deciduous in southern Scandinavia and Poland, to the hemiboreal mixed coniferous forest in southern Sweden, the Baltic Republics, Belarus and southeastern Russia, to the boreal coniferous forest types in central and northern Sweden, Finland and northwestern Russia. The forest in the Baltic drainage basin forms a unique case study for the development of sustainable forest ecosystem management in general. On one hand this forest region forms one distinct constellation of landscape types with a common set of disturbance regimes. These include successions after large-scale stand-replacing disturbances such as fire and wind, low-intensity fire in dry pine forests as well as internal gap-phase dynamics in spruce forest and broadleaved deciduous forest. On the other hand, different parts of the landscapes in the Baltic region have been subjected to different forest histories. In the mining districts of western Fennoscandia wide-scale clear cutting started hundreds of years ago. Intensive forest use then progressed to the north when the demand for forest products from Western Europe increased about 150 years ago, and to the northeast in response to the needs of the emerging Soviet Union (Angelstam et al. 1995, 1997). A similar development, which has occurred in different directions and rates, has taken place in the cultural landscape. As a consequence, remnant reference areas with largely intact biodiversity are still existent (e.g. Syrjänen et al. 1994; Falinski 1986; Mikusinski and Angelstam 1998; Volkov and Gromtsev 1999; see Figure 1).

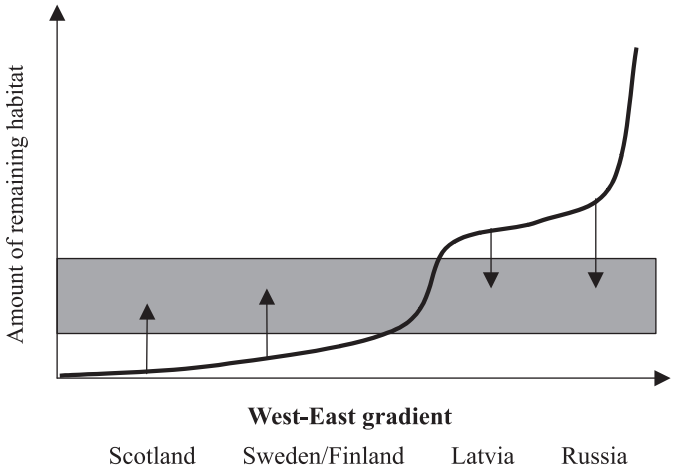

Figure 1. Illustration of the problem of trying to strike the balance between forest use and nature conservation in North European forests. The black line illustrates the range of remaining amounts of authentic habitat in the West-East gradient in Northern Europe. The darker horizontal interval represents the range of 10–30% threshold values (see text) to be exceeded for the maintenance in the long term of viable populations of forest specialists with large area requirements. Finally, the arrows represent the need for restoration in the West, and the need for proactive planning to avoid repeating western mistakes in the East.

Central Europe, and in particular the area of the former Habsburg Empire, has similar gradients in land use history between the West and the East (Gunst 1989). Due to the unequal economic relationships with Western Europe, there have been distinct differences in the rate and extent of landscape development among different parts of Eastern Europe. In regions located closer to Western Europe the influences of Roman law led to more private and less communal pattern of

peasant property. Beginning in the 15th century the attraction of West European markets fostered the development of large manorial farms using socage labour and modernised intensive agriculture. This zone included Finland and Estonia through Latvia, Lithuania, western Poland, Hungary, Croatia and Slovenia and forms the core of a Middle European region (Gunst 1989). Here, the influences from Western and Eastern Europe were mixed.

Further to the east, the effects of West European markets entered very slowly. Not until the end of the 19th century when railways facilitated large-scale exports of agricultural products did outside markets exert an influence on the local agricultural production. Landowners derived incomes from spheres outside the agricultural production. Peasants lived in systems of land communes and village communities that lasted into the 20th century. Hence, both from the top and the bottom there were strong forces that prevented agricultural modernisation. Moreover, the lower population density did not demand intensive techniques, so production remained extensive. As a consequence, traditional agricultural methods still survive into the 21st century. Traditionally trees have been found in many such forms of traditional of land use. The types range from wood-pastures (German *Weidewald*, French *paturages boises*) and wood-meadows as well as olive groves and orchards in the southern part of Europe.

Harmonising the evolutionary and cultural past with current management

The advent of the biodiversity debate has triggered a development of ideas about how forestry could partly emulate the conditions under which species have evolved (e.g. Fries et al. 1997; Angelstam 1998a; Björse and Bradshaw 1998). Because both the ranges of disturbance regimes in different forest types and the number of management methods are large, it is important to understand to what extent existing management methods harmonise with the evolutionary past of a given forest type (e.g. Angelstam and Andersson 2001).

However, considering only traditional forests is insufficient when assessing forest biodiversity (e.g. Kirby and Watkins 1998). Because of the rescue effect for forest specialists, the management of forest biodiversity in Europe must encompass not only forests in their traditional sense, but also a range of other environments with trees, as was the case in the old cultural landscapes (Figure 2).

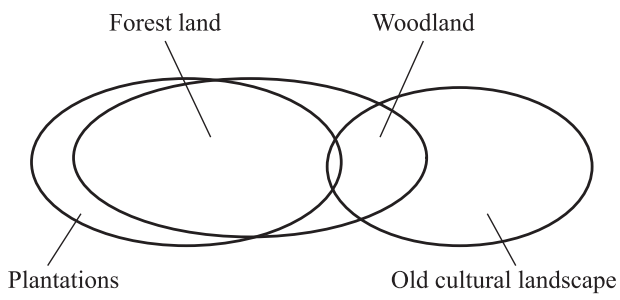

Figure 2. Defining forest biodiversity. While the most extreme form of forest management – recent plantations on agricultural land – is defined as forest from a forest production point of view, it usually satisfies very few of the forest specialist species. On the other hand, what is defined as farmland may have considerable amounts of natural forest components such as old trees.

It is imperative that the relative importance of both forests and cultural landscapes is evaluated. One approach is to compile and communicate both the ranges of natural and cultural conditions to which species' populations have adapted, as well as the range of management methods that are applied to forest biodiversity. This variety of combinations in the matrix, from bad to good, could be used to create a way to express the amount of habitat that has successfully been allocated to the maintenance of forest biodiversity (Table 4).

Table 4. In monitoring progress in biodiversity management the extent to which existing management methods harmonise with the evolutionary past should be understood. It is, therefore, both vital to understand the range of natural disturbance regimes (from Fries et al. 1997; Angelstam 1998a,b) and the resulting forest environments to which species have adapted (vertical dimension) as well as the different forest management regimes (horizontal dimension). If the degree of harmony between the two factors could be determined, the area extent of each matching or nearly matching management and disturbance regime could be used to assess the short-term achievements to the long-term goal of maintaining forest biodiversity. The signs illustrate in a tentative way the best combinations.

	Management Regime			
Disturbance Regime	clearcutting systems	shelterwood systems	selection systems	old cultural landscape
stand-replacing	+	–	–	(+)
cohort dynamics	–	+	–	(+)
gap dynamics	–	–	+	(+)

Conclusions

To ensure sufficiently rapid progress in the assessment, management and restoration of forest biodiversity three questions are identified as particularly important. First, quantitative benchmarks have to exist, against which biodiversity measurements can be compared to assess the progress in forest biodiversity restoration. This is particularly important because time lags in the response of species populations to habitat loss overestimate the viability of species. Second, a clear vision of the authentic (both natural and cultural) composition and structure of the forest ecosystem that species have evolved with, or adapted to, must be at hand. This can be sought by studying biodiversity in both altered landscapes and reference ecosystems in the steep gradients of land use history found in many parts of Europe. Third, in developing biodiversity measurements the extent to which existing management methods harmonise with the evolutionary past should be understood.

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Biodiversity Evaluation Tools for European Forests

T-B. Larsson

Swedish Environmental Protection Agency
Stockholm, Sweden

Abstract

The EU project 'Indicators for monitoring and evaluation of forest biodiversity in Europe BEAR', initiated in 1998, is a pan-European concerted action, bringing together expertise from 27 European research organisations to build a framework for the development of forest biodiversity indicators at various spatial scales. A report from the project 'Biodiversity Evaluation Tools for European Forests' is in preparation. In this paper the main achievements of BEAR are summarised: (1) agreement on a common scheme of key factors of biodiversity applicable to European forests; (2) identifying European-level Forest Types for Biodiversity Assessment; (3) presenting indicators of forest biodiversity; (4) recommendations for elaborating 'Biodiversity Evaluation Tools (BETs)' and establishing schemes of biodiversity indicators for assessment of forest biodiversity on a European level; (5) recommendations for elaborating 'Biodiversity Evaluation Tools (BETs)' and establishing schemes of biodiversity indicators for assessment of forest biodiversity on the operational unit level; and (6) highlighting the state-of-the-art of knowledge to present biodiversity indicators and the need for future research.

Keywords: biodiversity, sustainable forest management, forest policy, Criteria and Indicators, Europe, BEAR

Introduction

We certainly do not have the knowledge nor resources to perform a complete assessment of European forest biodiversity. This is no excuse for not taking action to mitigate the great threats to the biodiversity of European forests. The objective of this report is to briefly present recommendations for the development of Biodiversity Evaluation Tools (BETs) for European forests adapted to different specific uses. For example: forest managers with an operational tool for stand management with due regard to biodiversity conservation issues; administrational

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forestry organisations with an evaluation tool to assess, at the landscape scale, the effects of local forest management on the maintenance of biodiversity; and national organisations responsible for reporting the quality of Sustainable Forest Management strategies in terms of biodiversity conservation. A priority for the project has been to provide the Ministerial Process for Protection of Forest in Europe with a basis for improving the implementation of the Helsinki Resolution H2 ’General guidelines for the Conservation of Biodiversity in European forests’.

The BEAR Project

The EU project ’Indicators for monitoring and evaluation of forest biodiversity in Europe BEAR’, initiated in 1998, is a pan-European concerted action, bringing together expertise from 27 European research organisations to build a framework for the development of forest biodiversity indicators at various scales. The six major Biogeographic regions of Europe are thus represented according to Table 1.

Table 1. The BEAR project organisation. The Biogeographic regions follow those elaborated in connection with the EU Habitats Directive.

Function/ Biogeograhic Regional group	Organisation	Responsible scientists
Co-ordination	Swedish Environmental Protection Agency	Tor-Björn Larsson, *co-ordinator* Kjell Sjöberg, *assistant co-ordinator* Linus Svensson and Gunilla Andersson, *reporting and webservice*
Mediterranean and macaronesian regional group	Estação Florestal Nacional, Portugal	Francisco Rego, *regional co-ordinator* Susana Dias, *assistant regional co-ordinator*
	Jardin Botanico da Madeira	Fransico M. Fernandes
	Facultad de Ciencias del Medio Ambiente Universidad de Castilla-La Mancha, Spain	Federico Fernández-Gonzalez Orazio Ciancio, *responsible scientist* Anna Barbati
	Academia Italiana di Scienze Forestali	Piermaria Corona Marco Marchetti, *contact* Roberto Scotti
	NARF Forest Research Institute, Greece	Konstantinos Spans
Atlantic regional group	Centre for Ecology and Hydrology, Banchory, UK	Allan Watt, *regional co-ordinator*
	Forestry Commission Research Agency, UK	Richard Ferris Susannah Hall
	University College Cork, Ireland	John O’Halloran, Paul Walsh Paul Giller
	Wageningen Univ. And Research Center & Alterra, Green World Research, Netherlands	Frits Mohren Rienk- Jan Bijlsma

	Instituut Voor Bosbouw En Wildbeheer, Belgium	Kris Vandekerkhove Diego Van Den Meersschaut
	Laboratoire d'Entomologie Forestière, INRA, France	Hervé Jactel.
	Geological Survey of Denmark and Greenland	Richard Bradshaw Peter Friis Moller
Continental and alpine regional group	Forstliche Bundesversuchsanstalt, Austria	Georg Frank, *regional co-ordinator*
	Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Germany	Winfried Bücking
	Federal Research Centre for Forestry and Forest Products, Germany	Herrmann Ellenberg
	Universität Göttingen, Germany	Klaus Halbritter
	Universität für Bodenkultur, Austria	Ewald Rametsteiner
	Swiss Federal Institute for Forest, Snow and Landscape Research	Christoph Scheidegger John Innes Michele Keannel Dobbertin
	Eötvös Loránd University, Hungary	Tibor Standovár
	University of Ljubljana, Slovenia	Jurij Diaci Andrej Boncina
	INRA-SAD Toulouse, Terrestrial Ecology, France	Gerard Balent
Boreal regional group	Norwegian Institute for Nature Research	Björn Aage Tommeras, *regional co-ordinator*
	European Forest Institute	Janne Uuttera
	Unversity of Joensuu, Finland	Pekka Niemelä
	Swedish University of Agricultural Sciences	Per Angelstam Lennart Hansson
	The Forestry Research Institute	Lena Gustafsson

The work has been undertaken over a two year-period, to meet the following specific aims:

1. to analyse the important forest types in the six major European biogeographic regions with respect to their structure and function, in order to identify key parameters and determinants of biodiversity, adapted to the national level, the landscape level and the stand level;
2. to harmonise the classification of important forest types and suggest forest biodiversity indicators to assess key factors of biodiversity;
3. to summarise the applicability of indicators as regards ecological significance and data availability, including comments on assessment methodologies;
4. to discuss the recommendations with end-users, with particular reference to indicator feasibility; and
5. to synthesise the results into a strategic manual 'Biodiversity Evaluation Tools (BETs)', which can be defined as the combination of biodiversity indicators and the standardised methodology needed to apply them.

An extensive report from the project has recently been published (Larsson 2001). The main achievements of BEAR are:

1. *Agreement on a common scheme of key factors of biodiversity applicable to European forests.* Three primary aspects of biodiversity/ecosystems have been widely recognised: composition, structure and function. (Franklin 1988; Noss 1990; Perry 1994; Spies 1997). These components have been used as a basis for identification of key factors 'Key factors' affecting or determining biodiversity include abiotic, biotic and anthropogenic factors that directly or indirectly influence biodiversity and its major components (composition, stucture and function). The BEAR experts have agreed on a single common scheme of key factors relevant to all European forests (Table 2).

Table 2. A preliminary list of key factors of European forest biodiversity.

Scale	Structural key factors	Compositional key factors	Functional key factors
National/ regional	Total area of forest with respect to: - Legal status/utilisation or protection - Forest ownership - Tree species and age classes - Old growth/Forest left for free development - Afforestation/deforestation	Native species Non-native or not 'site original' tree species Forest types	*For all scales:* *Natural disturbance:* Fire Wind & snow Biological disturbance (incl. pests)
Landscape	Number and type of habitats (incl water courses) Continuity & connectivity of important habitats Fragmentation History of landscape use	Species with specific landscape-scale requirements Non-native or not 'site original' tree species	*Human influence:* Forestry Agriculture & grazing Other land-use Pollution
Stand	Tree species ('site original', 'not site original' and non-native) Stand size Edge characteristics (stand shape, ecotone, surrounding habitat) Forest history Habitat type(s) Tree stand structural complexity (horizontal and vertical) Dead wood (quality and amount) Litter (quality and amount)	Species with specific stand type and stand scale requirements Biological soil condition	

2. *Identifying European-level Forest Types for Biodiversity Assessment FTBAs*. The relative importance of key factors vary between different European forests as do the factors themselves (e.g. the species composition). The BEAR experts recommend that the management of biodiversity is based upon specific Forest Types for Biodiversity Assessment (FTBAs). Each FTBA is distinguished because of its particular features, i.e. key factors of forest biodiversity. A preliminary list of 31 FTBAs to be taken into account

on a European level is suggested (Table 3). Each FTBA has been defined to correspond to one or several units in a European Map of Potential Natural Vegetation (scale of 1:10 million). Furthermore, it is possible to relate the FTBAs to the CORINE classifications as well as to the priority habitats listed in the Habitats Directive.

Table 3. A preliminary list of Forest Types for Biodiversity Assessment (FTBAs).

Forest Type for Biodiversity Assessment
1. Subalpine conifer vegetation in nemoral zone
2. North boreal forests
3. Middle boreal forests
4. South boreal forests
5. Hemiboreal spruce and fir-spruce forest
6. Mixed spruce and fir forest
7. Mixed oak forest
8. Ashwood
9. Mixed oak-hornbeam forest
10. Lowland beech forests (lowland and sub-montane)
11. Montane mixed beech-fir-spruce forest
12. Mediterranean and Submediterranean mixed oak forest
13. Mediterranean broad-leaved sclerophyllous forests and shrub
14. Mediterranean and Macaronesian coniferous forests, woodlands
15. Atlantic dune forest
16. Ombrotrophic mires
17. Artic-subartic mires
18. Minerotrophic mires, swamp forest
19. Swamp and fen forests, alder
20. Swamp and fen forests, birch
21. Flood plain (alluvial and riverine) forests
22. Mediterranean and Macaronesian riverine woodlands and gallery forests
23. Laurel forest
24. Hedgerow
25. Chestnut coppice
26. Pine plantation
27. Spruce plantation
28. Poplar plantation
29. Robinia plantation
30. Eucalyptus plantation
31. Other plantation

3. *Presenting indicators of forest biodiversity*. The biodiversity indicators are the measures used to assess the key factors of forest biodiversity. For operational reasons the indicators need to be adapted to the special conditions of each Forest Types for Biodiversity Assessment (FTBA) as well as to the scale and other prerequisites of the specific use. During the BEAR project the experts have agreed that it is premature to define priority lists of indicators for operational use. This view has been proposed and accepted as the current EU position, with reference to the Convention on Biological Diversity. However, the BEAR project has presented a gross list of potential biodiversity indicators to assess each key factor of forest biodiversity, a preliminary example is given in Table 4.

4. *Recommendations for elaborating 'Biodiversity Evaluation Tools (BETs)' and establishing schemes of biodiversity indicators for assessment of forest biodiversity on a European level*. The BEAR project gives the following general advice, in priority order,

Table 4. Example of indicators to assess key factors of forest biodiversity. A tentative gross list of indicators to assess structural key factors of forest biodiversity at landscape level. The BEAR project will present 8 optimal indicator lists to cover the group of key factors listed in Table 2. Comments will be given as regards ecological significance of suggested indicators, current data availability and methodology for data collection. Note the list of indicators is presented by the BEAR project as options. The final choice of indicators should be made by the user based upon the specific prerequisites and preferences.

Assessment of structural key factors of forest biodiversity at landscape level:	
Key factor	Conceivable indicators
Habitat composition	Area of each type (FTBAs, Corine) of habitats (ha, ha of type/1000 ha)
Lakes and rivers	Lake/river presence: - Type (agreed classification scheme) and area/length; - Riparian zone type(s) and widths. Regulation and pollution status: - Presence/absence of unconfined rivers/streams; - Estimated volume organic debris per unit length.
Continuity & connectivity of important habitats	Measures of 'connectivity' e.g.: - Corridor length & width; - Proximity measures for different areas of particular habitats.
Fragmentation	Fragmentation measures, e.g.: - Specific habitat (esp. Forest) patchiness (patch size, absolute, % and rate of change) related to base-line; - Landscape graininess index related to base-line, (absolute and rate of change); - Total edge/ecotone length (m/1000 ha), specify type. Forest roads: - Road type(s), abundance (km /1000 ha).
History of landscape use	Qualitative and if possible quantitative description with respect to forest continuity: - Qualitative description of land-use favouring/disfavouring specific forest features (e.g. old trees, gaps, prescribed burning), hunting, grazing, etc.

for application in European and national level assessment, and monitoring of forest biodiversity:

- Introduce the key factor approach in European and national level monitoring of forest biodiversity;
- Make a further division into Forest Types for Biodiversity Assessment (FTBAs) in the reporting of each key factor;
- Standardise indicators, methodology and protocols.

5. *Recommendations for elaborating 'Biodiversity Evaluation Tools (BETs)' and establishing schemes of biodiversity indicators for assessment of forest biodiversity on the operational unit level*. Brief recommendations are given for elaboration of BETs for each scale and forest manager category.

6. *Highlighting the state of the art of knowledge to present biodiversity indicators and the need for future research.* It is demonstrated that because of the strong development of

biodiversity indicators and the insufficient current knowlegde it is premature to establish a standard monitoring scheme based on 'core' indicators. Five priority research areas to further develop Biodiversity Evaluation Tools for European forests and introduce these in operational use are identified:

- Validation of indicators of forest biodiversity;
- Establishment of reference values and critical thresholds for forest biodiversity;
- Biodiversity Evaluation Tools for assessment of genetic diversity of forest trees;
- Development of indicators for national monitoring of forest biodiversity;
- Strengthening landscape-level planning for forest biodiversity.

The BEAR project has, hopefully, contributed to an improvement in ecological understanding, communication and awareness among end-users responsible for the policy framework and operational management of European forest biodiversity.

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A Model Indicating Effects of Multipurpose Use of Forestry on Stand Level

Lennart Eriksson and Anders Lindhagen

Department of Forest Management and Products
Swedish University of Agricultural Sciences
Uppsala, Sweden

Abstract

Environmental factors are regarded and co-ordinated with timber production on stand level in the presented model. Biodiversity indicators are dimension graded amounts of living and dead wood. The proportions of deciduous tree species, large trees, passability by foot and sight between stems are relevant recreation factors. Three expressions are derived in the range from 0 (no value) to 1 (best estimated value) to illuminate effects on: (1) timber production; (2) biodiversity; and (3) recreation. The model is applied on forests in southern Sweden, transformed from monocultures of planted softwood stands, into naturally regenerated, mixed stands managed to achieve sustainability.

Keywords: nature indicator, recreation, biodiversity, environmental management, nature conservation, forest protection

1. Introduction

1.1 Background

The present forests of southern Sweden are dominated by managed conifer stands of low biodiversity, consisting mainly of Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). Acid rain, nitrogen deposition and excessive ozone levels reduce biodiversity and change the biogeochemistry of the stands negatively from environmental points of view. During the last century, increasing populations, increasing leisure time and expanding tourism from the European continent have focused the recreational aspects of forestry in the southern part of Sweden (Lindhagen 1996a). Simultaneously, the industrial use of roundwood and

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residual material from forestry is continuously increasing. Forestry must also be prepared for altered climatic conditions, most likely with an increasing average temperature favouring deciduous trees. The need of a multipurpose planning system to co-ordinate different interests in the forests and the forestry is more evident than ever before. The multiple-goal perspective is also in accordance with the current Forestry Act in Sweden.

Within a research programme, 'Sustainable Forestry in Southern Sweden', some hypotheses have been formulated in order to facilitate the transformation of forests poor in species diversity, e.g. planted mono-cultures of Norway spruce, into a more diverse and sustainable status. The hypotheses are:

- increased natural regeneration and an increased proportion of deciduous trees in the forests, simultaneously avoiding large clear fellings and plantations, will increase the sustainability as regards soil fertility and biodiversity;
- forest health will improve when nutritional balances are achieved, and the leaching of acid elements and nitrogen will be decreased by using the above principles for silviculture, but the total economy of forestry (given some special efforts) will be just as good as before;
- soil fertility must be retained by addition of missing macro- and micro-elements. This will guarantee sustainable productivity and better sustain biodiversity and forest health;
- modelling the natural variation concerning forest productivity and forest damage effects, biogeochemical cycles and biodiversity, will considerably improve our understanding of how to manage forests in a sustainable way in the future.

The consequences of transforming the forests may be analysed on varying geographic scales from stand level to the perspective of an entire landscape (Fries et al. 1998). At the stand level it is possible to regard and analyse interactions between interests of single treatments of well described forest areas (Eriksson and Eriksson 1993). At the level regarding a group of stands within a geographically limited area, aspects such as logging economy (Eriksson 2000), recreational effects of the concentration of logging or forest management system (Kardell 1990; Lindhagen 1996b) as well as some biodiversity factors (Angelstam 1992) can be studied. At the level of a forest estate, the treatment decisions are normally co-ordinated and the economic consequences may be followed up (Jonsson et al. 1993; Ekvall 1999; Eriksson et al.1989). There is, however, still a need of oversight in a larger perspective covering patterns of a landscape extending over thousands of hectares because of the movements of some species, as well as effects of the mix and the composition of forest stands on recreational consideration (Fries et al. 1998).

1.2 The purpose of the study

The aim of this sub-project, within the research programme mentioned, is in the perspective of multiple-use of forest resources to evaluate economic consequences of the transformation of forests, poor, for example, in species diversity, into more sustainable forests in southern Sweden. The objective of the study is to examine the effects of different treatment regimes at the stand level. This is a necessary first step to be able to regard questions at higher, geographic or administrative levels. Estimations of treatment effects on timber production, biodiversity or recreational aspects found at the stand level will be related in other studies in the programme to perspectives at higher levels.

Another restriction of this study is that it only embraces areas for timber production with varying degrees of consideration to other interests. Areas, forested or not, left for free development or treated with the main purpose to support environmental questions are not involved.

2. Method and Material

2.1 The planning model

Methods for analyses of multiple goal problems in forestry originated in the 1970s from mathematical programming and resulted often in multiple objective linear programming (LP) problems. LP has been used to solve well-structured problems where goals either are expressed in an objective function or as a constraint of the optimal solution (Dyer 1973; Wallenius and Zionts 1976). Since then, emphasis has shifted from reaching global optima with certainty to problems of how to provide the best possible support to the decision-maker.

Focus has now changed to the question of how to present appealing suggestions to the decision-maker by means of communication facilities. The process of problem solving must be a part of the organisational context. The entire decision process from problem identification to decision implementation should be supported (Korhonen and Wallenius 1995). By means of multiple criteria decision support systems it should be possible to give answers to questions such as 'how to achieve a specified status' rather than examining 'what will happen if'. A method developed for the former objective is back-casting. The process of analyses starts with a description of a desired status of future forestry, fulfilling defined purposes for wood production as well as recreational and biodiversity values. The next step is to analyse how to achieve the goals from an actual situation. By the chosen method we can more easily look beyond limitations of everyday problems (Ritchey 1991).

Essential information is often not at hand in the planning situation ('what goals do the forest owners have for their forestry?'), and important processes cannot be satisfactorily analysed ('which is the optimal range of the trees to be cut and when during the rotation will each tree be cut?'). The use of a forecasting model as a communication instrument in the planning process would then be preferable to decision-making by means of 'optimised' solutions.

2.2 Forecasting stand development

The model used for forecasting the development of single trees and stands (Söderberg 1986; Jonsson 1974) is estimated on a large material of inventoried plots from the National Forest Survey (thinning response, however, emanates from experimental plots). This means that the stand prediction after treatment will give an average response to volume growth, diameter increment, etc. The simulation system is, as regards the main structure, developed and presented by Eriksson and Eriksson (1993) and Eriksson (1994).

The simulations are deterministic, in the sense that the result will become exactly the same if restarting with the same data input and also that the used costs and prices of roundwood are constant over time. The model used for analysing the treatment programmes for stands allows specification of the number of thinning treatments, their strength and form by choosing the cut of single trees at each possible time of thinning or at final cut. By implementing fixed logging costs for each treatment in the calculation, the number of cuts over the rotation age will be reduced for economic reasons.

Two regeneration methods may be simulated, natural regeneration and plantation, with or without scarifying. Plant density at plantation and the number and time-points of pre-commercial thinnings, may be specified. For natural regeneration, time delay for plant establishment (–7 years) and reduced growth speed (–10%) is given by G Örlander (personal communication, G. Örlander 1999).

Three assortments, two for timber and one for pulpwood, have been selected for the cross-cut of both softwood and hardwood tree species. For the forestry activities, production efficiency,

costs and revenues are derived as mean values from the market in southern Sweden during four years at the end of the 1990s, embracing one economic cycle. The revenues vary due to the direction of the treatment program towards high- or low-grade timber. Net present values for activities during the rotation periods are calculated based on a real rate after taxes of 3%. The simulations are based on soil expectation values calculated on the assumption of plantation of spruce or pine and a traditional stand treatment. The used values are:

Site index class, m (T, pine; G, spruce)	Soil expectation value ’000 SEK/ha
T24	2.9
T28	10.7
G28	5.5
G32	27.3
G36	37.9

2.3 Indicators of sustainable forestry

2.3.1 Wood production

Wood production indicators have successively been developed during the last century. They have been tested and established in the forestry of today (Lundström et al. 1993). The motive for wood production is the market for roundwood, and as a consequence, the harvested volume of roundwood. Because of the influence on harvest economy, the volume cut should be distributed over average stem size at cut as well as over delivered saw logs and pulpwood. Variable costs and revenues of activities give the net value and the contribution to cover fixed costs and to support the liquidity of the forestry.

The state of the forestry as an input in a forecasting model generates consequences in the shape of the future cut, need for silviculture, economy and the change in forestry state. This can be viewed in different dimensions. Actual volume increment gives a good estimation of cut potential in the long perspective, but not for periods shorter than 2 to 3 decades (in Swedish forestry). Standing volume, on the other hand, gives the short-term potential. Stem density is an indicator of the need of silvicultural treatments such as regeneration, pre-commercial thinning and low thinning. The distribution of age classes in a forest ownership gives information about future changes in economy and is therefore the link between the short- and long-term perspectives. The mix of tree species and the average diameter in stands is important information for estimation of future profit of the forestry. Net present value of all future costs and revenues of forestry is a good summary of the wood-producing economy. The variation in economy over time is not, however, described by means of this measurement. Analyses on stand level deliver these variables for considerations on the level of the forest estate, etc.

2.3.2 Biodiversity

Compared with wood production, biodiversity is a new field of science, the numerous species to consider and the complexity in natural forest ecosystems making the problem area large and difficult. As the goal of this sub-project is reduced to analyse treatment alternatives to transform single stands, and the main purpose in the stands is to produce wood for sale, a number of aspects and indicator variables that are relevant in other situations may be excluded. Such variables are, for instance, the distribution of stands and treatments over the

area, reserved areas, areas that are fertilised, ditched, burned or non-forested, as well as the area of agriculture. Some of these aspects are involved in the discussion of this paper.

The main objective of biodiversity in forestry today, according to the Swedish standard of Forest Stewardship Council for forest certification, is the endangered species, in this case those occurring in forest ecosystems. The mix of tree species has a major influence on the number of endangered species in a wood-producing forest stand (Almgren 1990). Which tree species are the most valuable with regard to the endangered species, can be studied in collations of endangered species associated to tree species (e.g. Ahlén et al. 1979). Especially large stem diameter and high age are important factors for survival of a large number of endangered species (Esseen 1996). Continuity, as regards the environment for survival of endangered species, is a prerequisite especially for those species adapted to a life in undisturbed, i.e. non-burned areas (Fritz 1997; Nilsson 1997; Andersson 1997). This latter factor, which only can be relevant for areas known to be undisturbed during centuries, interacts with other factors such as the occurrence of big old trees, natural regeneration, etc.

A specific factor of importance for endangered species is dying and dead wood. A too careful cut of trees damaged by wind, snow, drying, crowding, etc has resulted in a lack of dead wood in Swedish managed forests (Ahlén et al. 1979). This is mainly the situation for large old stems (Bernes 1994). Therefore, it is necessary to re-establish this factor into a more natural state. It is logical that dead wood of rare tree species, such as large individuals of deciduous tree species, is the more valuable in this respect.

The conclusion is that the actual amount of dead wood is an important factor for biodiversity. The coarse woody debris (CWD) i.e. dead wood including snags (standing dead or dying trees), stumps, logs, large branches and pieces of roots (Samuelsson et al. 1994), serves as cover, feeding, reproduction, etc for mammals and amphibians and as habitat for less advanced animals, plants and fungal species. Different parts of the wood are used by different species. Some species are specialised to use the cellulose as basic food, others the lignin, while some use the stem as cover, etc.

The commonly practised method to measure and estimate the decomposition of dead wood is to study the loss of mass in, i.e. boles of dead trees. Henningsson (1967) and Tamminen (1979) have studied the decay of stored pulpwood in different parts of Sweden, and Lambert et al. (1980) the decay of dead wood in a sub-alpine natural forest of balsam fir. Lambert found that high decay rates were attributed to small bole diameter, high moisture and a nitrogen-rich environment. He also found that the content of cellulose, lignin, carbon and sodium followed the loss of mass, while the amount of calcium, magnesium, potassium and phosphorus decreased faster. Lambert's results often show a decline of mass over time, which, after a short lag period, decreases slightly with increasing age of the bole. The lag period can be explained by the process of establishment of decaying organisms in the bole. Henningsson stresses that climatic factors, especially the length of the growing season, are very important for the decomposition of wood. After a short lag time period (about half a year) when the decaying organisms advanced from the ends of the logs, the loss of mass increased drastically with increasing time of storage. After two and a half years, including the lag time, the dry density was decreased to 75% on pulpwood of birch in a plot situated in Ryd in southern Sweden. The corresponding value for aspen was about four years. Tamminen (1979) found that in southern Sweden (Simlångsdalen) that Scots pine has a slower decay rate (12% of loss of dry mass during 3.5 years) than birch (19%), and Norway spruce was still slower with 3%. The figure for birch deviates from Henningsson's, which may be explained by prevailing weather conditions. Tamminen concluded that the specific drying speed of wood of different tree species is an important factor behind the differences in wood decay rate. The conclusions as regards the task of this study are that: these variations may exist even at ground level in the forest, but at a far lower level; and that litter fall (in the form of leaves, branches, etc.) will increase the process of decay of stems. The stems are not cross-cut (but may

be broken by storm felling) and the bark will protect the wood from fungus attacks for a while. Christensen (1977), analysing the turnover of dead wood in a Danish oak stand, found that the length of time for loss of half the dry mass of the wooden part of litter fall was as long as 17.7 years. He supposed that large fallen stems of oak would lie, without any significant degree of decomposition, for a decade or more.

Harmon et al. (1986) discuss models for losses from coarse woody debris (CWD). Most of the existing models use exponential functions as:

$$Y_t = Y_0 \cdot e^{-kt}$$

where: Y_0 is the initial quantity of material;
Y_t is the amount left at time t; and
k is the decay rate constant.

The decay is proportional to the amount of remaining material according to this model. Multiple-exponent models may be used to differentiate for varying decay rates of bark, sapwood and heartwood. Also delay time may be included in this model type. Many other authors have shown attempts to adapt parameters in exponential models on decay materials, often with good results (Lambert et al. 1980; Christensen 1977).

Authors studying the decay of wood normally present their material in terms of half-time, the point of time when half of the dry material is lost. Still, there is a lack of relevant research material compared with the ambitions of this study. The figures roughly estimated and used in the analyses are, however, based on results from the above-mentioned authors.

The problem of mortality in managed forests has been studied by Bengtsson (1978; 1979). His material emanates from the Swedish national forest survey. Other Swedish attempts use more limited material and are not referred to here. Hägglund (1981) has divided the mortality into three groups:

1. regular mortality caused by crowding;
2. Irregular mortality caused by storms, droughts, small forest fires, etc.
3. Catastrophic mortality caused by unpredictable hurricanes, insect population explosions, etc.

The third category is completely unpredictable and is not regarded in this study. The first one is estimated by means of an expression built on the basal area of the stand. The second has the age class of the actual stand as an independent variable. These mortality functions are applied on trees with diameters at breast height larger than 40 cm, which may be discussed since tree size ought to have an influence on the probability of mortality. However, no alternatives are at hand.

The biodiversity indicator must be able to communicate treatment effects easily to decision-makers, and other interests in forestry. It would be preferable if the most important factors could be gathered in one expression comparable between objects. As with other products in demand, the first unit often is the most valuable and thereafter the value of next unit gets smaller, until finally one more unit gives almost no additional value. This kind of a relationship can be described by an exponential expression such as:

$$K = 1 - e^{-(\alpha + \beta x_1 + \chi x_2 \ldots)}$$

where: K is the total effect of a couple of products in the range between 0 and 1;
x_1, x_2, ... are the amounts of products; and
α, β and χ are estimated parameters.

One argument towards an application of an exponential function to describe biodiversity effects is that the first unit gives very little effect. It is not until the achievement of a minimum amount that the effects will increase (one swallow does not a summer make). This argument may have some relevance in a situation with very low biodiversity values in surrounding stands.

As protection of endangered species is the definition of biodiversity in this article, Ahlén et al.'s (1979) placing of endangered species together as regards connections to tree species and dead wood originating from tree species is the starting-point for the application of the model above. Oak is the most valuable tree species in this list, with 10 endangered species associated with large living trees and 18 to large dead trees. The ambition is to let an old oak stand in this study represent the full biodiversity value 1. The practical solution of the problem is to give the standing volume above 40 cm at breast height in a 100 year old stand (Carbonnier 1975), and the accumulated amount of dead wood above 40 cm, a biodiversity value of 0.8 by means of two oak parameters, one for large living tree volume and one for large dead tree volume. Parameters for other tree species are related to the oak-values depending on the associated number of endangered species.

The adapted expression for biodiversity used in the analyses is now:

$$BIO = 1 - e^{-(PL_t \cdot VL_t + PD_t \cdot VD_t \ldots)}$$

where: BIO is the total biodiversity effect in a stand (with the given constraints),
PL_t is the biodiversity parameter for living trees > 40 cm of tree species t
VL_t is the standing volume of living trees > 40 cm of tree species t
PL_t is the biodiversity parameter for dead trees > 40 cm of tree species t
VL_t is the accumulated volume of dead trees > 40 cm of tree species t

The model for description of the decay of large dead trees is based on the half-time exponential function. Let us begin with the assumption that we know the half-time value for decay of a specific tree species, T. The remaining amount of wood $V(t)$ after t years and with a starting amount of B is expressed by:

$$V_{(t)} = B \cdot 2^{-\frac{n}{T}}$$

We know the amount of fresh wood at the start of a period of, for example, 10 years and during this period we assume that the contribution of fresh dead wood by mortality is constant and is given at the beginning of each year. The amount of fresh wood after n years is then:

$$V_f = B \cdot 2^{-\frac{n}{T}} + \sum_{k=0}^{n-1} N \cdot (2^{\frac{-k}{T}})$$

where: N is the annual contribution of fresh dead wood
k is the current year
T is the decay half-time

This is the sum of a geometrical array. The sum of this array, V_f, in year n during the period may be transformed into:

$$V_f = B \cdot 2^{-\frac{n}{T}} + N \cdot \frac{1-(2^{-\frac{1}{T}})^n}{1-2^{-\frac{1}{T}}}$$

which is the expression used to estimate the amount of remaining dead wood after a period when the input amount and the annual contribution of fresh dead wood is known as well as the half-time values for wood decay.

The used parameters in the simulations are estimated based on the literature cited. The parameters are shown in Table 1.

Table 1. Estimated biodiversity parameters

Tree species	No. of endangered species on living trees	Parameter PL	No. of endangered species on dead wood	Parameter PD	Half-time for decay of wood, years
Oak	19	0.008	28	0.012	20
Birch	1	0.0004	13	0.0056	3
Ashes	No value	0.004	No value	0.006	10
Scots pine	3	0.0013	15	0.0064	5
Norway spruce	1	0.0004	10	0.0043	4

2.3.3 Recreation

The forest of southern Sweden is frequently used for outdoor recreation purposes . The median Swede is visiting a forest for recreational purposes about once a week during the summer and about once a fortnight in winter (Lindhagen and Hörnsten 2000). To understand how forestry can be adapted to better suit the preferences of outdoor recreationists research concerning public preferences of forest sites has been conducted since the 1970s in the southern Scandinavian region (Hultman 1983; Koch and Jensen 1988). These studies have been repeated during the late 1990s which enables some conclusions regarding the stability of the preferences over time to be stated (Jensen and Koch 1977; Lindhagen and Hörnsten 2000). All studies mentioned are based on nation-wide postal inquiries sent to a representative selection of Swedish or Danish citizens. Black-and-white photos are used to describe the forest stands. In several investigations, black-and-white photos have proved to be suitable for assessment of forest views if they are carefully exposed and selected (Savolainen and Kellomäki 1981; Hultman 1983; Kellomäki and Savolainen 1984; Lindhagen 1996).

In other parts of the world, studies using tree vegetation variables to predict the recreational value or the amenity of a tree stand have been conducted. In a Finnish study, about 70% of the variation in the public's judgements of different forest stands could be explained by forest stand indicators such as number of stems/ha, average stem diameter and stem volume per hectare (Pukkala et al. 1988). A similar degree of explanation was found in an Appalachian study predicting the effects of the Gypsy moth on near-view aesthetic preferences and recreational aspects (Hollenhorst et al. 1993). In the latter study, tree mortality was the outstanding predictor. In a field study in Sweden, it was found that the forest stand's

passability by foot was the most important predictor to explain forest suitability for outdoor recreation (Lindhagen 1996b).

Recreational values can, as shown above, be predicted in forest stands using predictors describing the tree vegetation. In this study, the result of the latest Danish and Swedish studies (Koch and Jensen 1997; Lindhagen and Hörnsten 2000) have been used to develop linear regression models to predict the forest recreation value. In the investigations, the forest sites were given points corresponding to how they ranked related to other forest stands according to the respondent's outdoor recreation preferences. The mean values for these points have been used as the dependent variable when creating the regression models. The following three regression models were established and have been used to estimate the recreation value (REC):

1. Clear-cut areas and young forest with trees lower than 2 metres:

$$REC = 0.3 + 0.1 \cdot uneven - 0.01 \cdot deadtr - 0.02 \cdot lystem - 0.01 \cdot res$$

2. Young forest with trees higher than 2 metres and before the first commercial thinning:

$$REC = 0.568 - 0.0004 \cdot pinepr - 0.0202 \cdot sprupr + 0.169 \cdot uneven$$
$$- 0.0009 \cdot stsm - 0.063 \cdot deadtr - 0.0965 \cdot lystem - 0.019 res$$

3. Forest after first commercial thinning:

$$REC = 0.569 + 0.0106 \cdot broapr + 0.0491 \cdot uneven - 0{,}000076 stsm$$
$$+ 0.000103 stmed + 0.00176 stla - 0.058 \cdot deadtr - 0.099 \cdot lystem - 0.0639 res$$
$$- 0.0549 \cdot grodam$$

where: *pinepr, sprupr and broapr* are the proportion of Scots pine (*Pinus sylvestris*), spruces (*Picea* spp. and *Abies* spp.) and broadleaves (mostly *Betula* spp., *Fagus sylvatica* and *Fraxinus excelsior*), respectively;
stsm, stmed and stla are the number of stems per ha in the diameter classes 5–20 cm, 20–48 cm and above 48 cm, respectively;
uneven have the value 0 if the forest is evenaged and the value 1 if the forest is unevenaged;
deadtr is the amount of dead standing trees (snags) on a scale from 0 (none) to 3 (the stand is totally dominated by dead trees);
lystem is the amount clearly out of their perpendicular or lying on the ground on a scale from 0 (none) to 3 (the stand is totally dominated by lying trees);
res is the amount of logging residues on a scale from 0 (no logging residues) to 3 (the stand is totally dominated by logging residues); and
grodam is the degree of damage on the ground on a scale from 0 (no ground damage) to 3 (very large damages on the ground).

3. Results

The analyses are performed to give answers to the hypothesis presented in the introduction of this paper. The first treatment alternative presented under one hypothesis is a reference giving the effects of continuing the forestry in accordance with traditions. The second alternative is the change in order to fulfil the ambitions of the hypothesis. If necessary, two forest

generations for each alternative will be analysed. At any shift of stand generations, ten trees per hectare of a mix of spruce, pine, birch, aspen or oak are protected from cut as a general environmental consideration in accordance with Swedish negotiations between the forestry and different environmental movements.

Stand 1

In this case a transformation is performed of a middle-aged stand of 90% of Norway spruce into a mix of birch and spruce. At the end of the second period, again spruce will dominate. The starting stand emanates from type stand No G 502 (Bredberg 1972). The site index class is G28 (the Swedish index system based on dominant height at 100 years).

Reference alternative
The starting point of the analyses is at a total age of 33 years. The stand is dominated by 90% spruce. The rest is an overstorey of birch with 20 cm basal area weighted diameter. After three intermediate thinnings (thinning form 1.0), a clear-cut is performed at the age of 78 years followed by scarifying, plantation of spruce and a similar treatment with three intermediate thinnings, etc., in the new stand. The treatment program is supposed to give normal timber quality.

The reference programme gives a high volume production, 8.0 cubic metres per year and hectare in the first generation (the first 33 years not regarded) and 6.4 in the second. The share of timber in the clear-cuts are 180 of a total cut of 289 cubic metres in the first and 225 of 331 in the second generation. A consequence of these figures is a high net present value of the programme from start including all future generations, 61.5 kSEK per hectare. The biodiversity factor, BIO, is, however, 0 during the entire first generation, since no dimensions achieve 40 cm diameter. During the second generation BIO achieves 0.1 because of the constant growing the ten trees left at the final cut. The recreation value, REC, increases from about 0.4 to about 0.62 during the first generation. After each thinning the value decreases with about 0.2. The clear-cut period and the young dense spruce forest in the beginning of the second generation achieves low recreation values (0.2–0.27). After the first commercial thinning the value increases fast but due to the slowly increasing amount of dead or lying trees the recreation value of the mature second generation becomes slightly lower compared with the first generation.

The multipurpose alternative
Hypothesis: Hardwood as a transit generation between two spruce stands will give at least the same total utility as spruce after spruce.

From the same starting point, the alternative treatment programme aims to successively reduce the stem No into a regenerating shelterwood system consisting of large birch in an overstorey (40% of standing volume) and spruce (60%) below. The next generation consists of a stand mixed of spruce and birch of about the same height and amount. Birch is cut stronger after half-time of the rotation. A few stems of spruce and birch achieve 40 cm diameter at the end of the second generation. A light cut from above in the thinnings result in higher logging nets than in the reference. Together with better timber quality and reduced costs at the natural regeneration the result is that the net present value (62.9 kSEK) exceeds the reference by 1.4 kSEK. The biodiversity factor achieved the level of 0.15 at the end of the second generation. The recreation value of the first generation increases faster than in the reference alternative and reaches 0.72 just before the clear-cut. The values during the regeneration period stays on a relatively high level (about 0.4). The recreation value in the end of tree generation 2 is about 0.64 which is higher than the reference alternative but lower than the first generation.

Stand 2

After a clear cut of a stand of spruce on a good site, ashes will be planted in the new generation. The starting status is a clear-cut area on good site index class, G36 m.

Reference alternative
The reference alternative is in this case similar to the second generation in the reference of alternative No 1., but with production of spruce on a better site. The result, including the costs of regeneration, is a high net present value, 13.7 kSEK. BIO increases up to 0.15 at the end of the simulated generation. REC is low for the clear-cut area and young dense forest. After the first commercial thinning the value increases and reaches 0.61 in the end of the first generation. The second generation achieves a slightly lower recreation value due to higher amounts of dead and lying trees.

The multipurpose alternative
Hypothesis: Plantation of ashes to produce wood of high quality will give at least the same total utility as plantation of spruce on a better site.

The plantation of 2500 plants of ashes is fenced and the ground is treated with herbicides. After one pre-commercial and seven commercial thinnings a clear-cut ends the rotation at 60 years age. The average volume production is 6.8 cubic metres per hectare and year (Carbonnier 1947). The net present value is 13.9 kSEK. Since some trees will achieve 40 cm diameter at the end of the period, the biodiversity factor rises to the level 0.3. The recreation value is much higher compared with the reference alternative especially for the period of young dense forest (REC = 0.5). The mature stand achieves a value of about 0.7 before the clear-cut. The second generation have a slightly lower recreation value.

Stand 3

A dense naturally regenerated young stand of Scots pine is treated to produce high-graded timber. The starting stand is a generated young stand mixed of Scots pine and birch based on pre-commercial thinning experiments (Pettersson 1992). Site index class is T24.

Reference alternative
In one strong pre-commercial thinning all birch is eliminated. After two strong commercial thinnings and a clear-cut, the area is scarified and planted by Scots pine. This programme gives a high volume production (5.2 cubic metres in the first and 5.5 in the second generation), but worse timber quality. The net present value of future stand generations is 23.3 kSEK. The biodiversity factor is 0 in the first generation of the reference alternative. In the second generation the generally protected trees give a BIO-value of 0.15 at the end of the period. The recreation value is about 0.37 before the first commercial thinning when the value decreases to about 0.3 due to logging residues before it rapidly increases to about 0.6. The second generation has a slightly lower recreation value.

The multipurpose alternative
Hypothesis: Production of high-grade timber by means of natural regeneration and an intensive treatment program gives at least the same total utility as clear-cut and plantation of pine.

An introductory pre-commercial thinning at 1.2 metres height to 4500 plants per hectare is followed by another one to 2000 stems per hectare at 6 metres height. One first intermediate thinning and two thinnings from above result in production of high-graded timber. The next

naturally regenerated stand is treated in a similar way. Volume production is lower than in the reference (3.3 cubic metres in the first and 4.2 in the second generation). The net present value is 16.3 kSEK per year and hectare for all future stand generations. The biodiversity factor, BIO, has achieved the value 0.15 at the end of the second generation. The recreation value is during the whole period slightly higher compared with the reference alternative.

Stand 4

An old grazing farm area abandoned for natural afforestation is used for selective forestry. The starting stand is an inventoried stand from a forest estate in Halland. The stand is mixed of an overstorey of birch, oak and pine and an understorey of spruce. The diameter distribution is wide. Site index class is G28.

Reference alternative
The stand is clear-cut followed by scarifying and plantation of spruce. A high standing volume (455 cubic metres per hectare) gives a high net present value of 137.0 kSEK per hectare. The biodiversity factor, BIO, has increased from 0 to 0.15 during a studied period of 115 years in this reference alternative. The recreation value decreases after the introductory clear-cut (Fig. 1.). The dense young spruce forest achieves a value of about 0.2. After the first commercial thinning the value increases and it amounts to about 0.58 at the end of the first generation. The second generation shows a similar slightly lower development of the recreation value.

The multipurpose alternative
Hypothesis: The creation of a multi-storied stand by successive thinnings will give at least the same total utility as clear-cut and plantation of spruce.

By thinnings from below and with priority for cut of spruce each tenth year an overstorey of big broad-leaved trees is created as a shelter-wood for natural regeneration of mainly broad-leaves. The successive cuts endless repeated in the future gives a net present value of 77.4 kSEK per hectare. The biodiversity factor varies during the period between 0.5 and 0.7, initially depending on a large amount of trees just above 40 cm diameter, and after some decades depending on some very large trees. The recreation value is high (0.6–0.75) during the whole period (Fig. 1).

4. Discussion

The analyses of the four stands illustrate well the difficulties to achieve high levels of the factors BIO and RNPV simultaneously. This is primarily a consequence of setting the required rate of interest at 3%; this leads to cutting of trees and stands as soon as they achieve d.b.h. above 30–35 cm. In other words, there are no old, large trees in an economically well treated stand. The protection of ten trees towards future cut is, in this situation, a necessary part of multipurpose forestry. A lower rate of interest (e.g. 2%) is probably a relevant level for many forest owners, and would allow the two factors, BIO and RNPV, a better chance to be achieved.

In our study, the public preferences of the late 1990s have been used to estimate the recreation value during the whole estimation period including two tree generations (approximately 150–200 years depending on silvicultural method). Public preferences according to forest stands and different forest management strategies change over time. In the

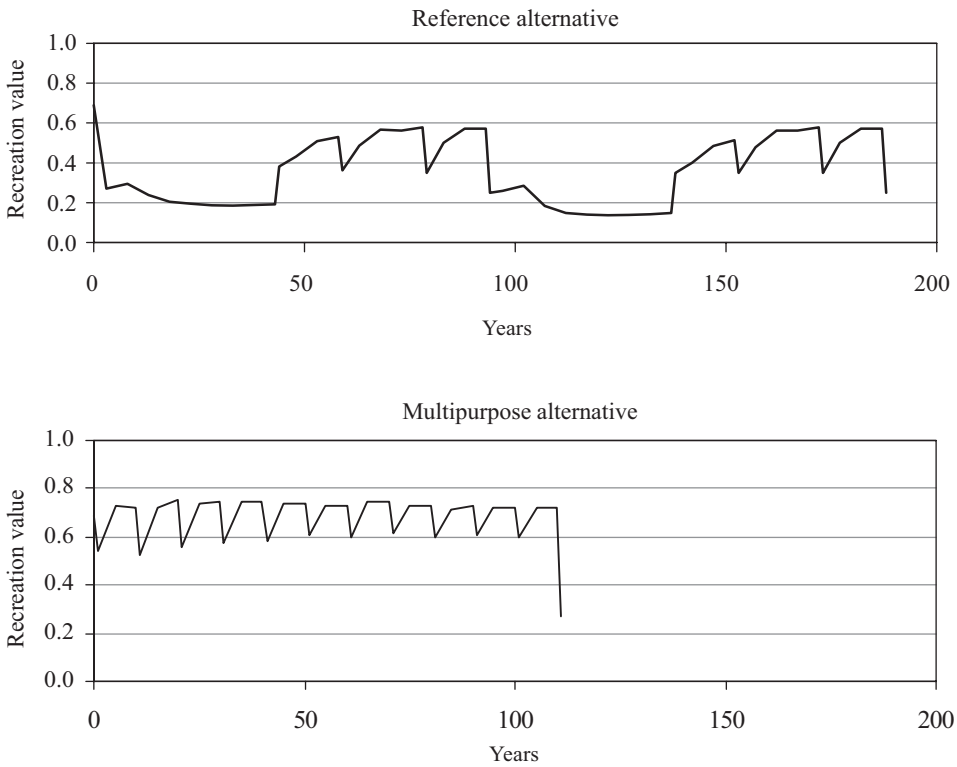

Figure 1. Stand 4. An old grazing farm area abandoned for natural afforestation is used for selective forestry. A comparison of the recreation values between the reference alternative (clear-cut followed by scarifying and plantation of spruce) and the multipurpose alternative (creation of a multi-storied stand by successive thinnings).

relatively few studies of trends in forest recreation, these changes have been shown to be small, at least when studied over a decade or two (Lindhagen 1996a; Jensen and Koch 1997; Lindhagen and Hörnsten 2000). Lindhagen and Hörnsten (2000), however, found that a more natural forest with a few wind-throws was slightly more appreciated in their study in 1997 compared with results from a study in 1977. This kind of forest site was generally given a very low value compared with managed forests in 1977, but in 1997 the proportion of respondents preferring this kind of site had risen to about 10%. These changes were even greater among young people (aged between 16 and 25 years).

The multipurpose alternatives show, as regards the economy of wood production, about as good results as the reference in Stand 1 (with natural regeneration of birch and spruce instead of planting spruce) and in Stand 2 (with plantation of ashes instead of spruce). As an extra bonus, these two multipurpose alternatives show better values when considering the BIO and REC factors. In other words, the total utility is higher by applying the multipurpose alternatives in the first two stands. This conclusion must, however, be regarded just as an interesting option by the decision maker, and not as a management rule. It is also to be noticed that the amount of wood produced is highest in the reference alternatives; however, the value per cubic metre of timber produced is higher in the multipurpose alternatives. The latter fact is an indication of more stable future revenues

In Stand 3, strong thinnings and a short rotation as in the reference will give far better economy compared with the multipurpose alternative. An important factor behind this result is the much higher volume production in the reference due to rapid growth after the early and strong pre-commercial thinning. This is a situation when pruning probably would be a realistic high-grade production alternative. Remarkable is the very modest effect on BIO and REC in the multipurpose alternative.

With regard to BIO and REC, Stand 4 shows a markedly lower logging economy by applying a successive cut in order to transform the stand into a more valuable status. On the other hand, the level of these two factors is achieved so rapidly and is so pronounced that it would be worth the cost to choose the multipurpose way in this stand. The administrative decision, if the stand should be regarded as a resource to fulfil biodiversity goals on the level of a forest estate or if the community should buy the rights to cut in the stand, must be considered above the stand level.

The overall conclusion is that variety in tree species, regeneration methods and treatment programmes, will give better opportunities to meet future changes in public preferences as well as changes in timber or pulpwood prices.

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Parameters for the Assessment of the Predisposition of Spruce-Dominated Forests to Various Disturbing Factors with Special Regard to the 8-toothed Spruce Bark Beetle (*Ips typographus* L.)

U. Nopp[1], S. Netherer[1], O. Eckmüllner[2] and E. Führer[1]

[1]Institute of Forest Entomology, Forest Pathology and Forest Protection,
University of Agricultural Sciences, Vienna, Austria
[2]Institute for Forest Growth and Yield Research,
University of Agricultural Sciences, Vienna, Austria

Abstract

In view of the decreasing capacities of forest enterprises for forest protection in general, the importance of preventive forest protection concepts steadily mounts. An instrument including numerous indicators has been established, which facilitates the detection of stand and site situations predisposing to various disturbing agents, and which allows the deduction of preventive management strategies. Revealing the potential of damage prevention, the so-called 'award penalty point systems' can support the process of silvicultural decision-making. Hazard assessment and system verification is demonstrated with a simplified estimation system regarding the predisposition of sites and stands to the 8-toothed spruce bark beetle (*Ips typographus)*.

Keywords: preventive forest protection, assessment of predisposition, Ips typographus, 8-toothed spruce bark beetle, Picea abies

1. Introduction

Regarding the decreasing availability of personal as well as financial resources of forest enterprises for issues of forest protection in general, the importance of preventive forest protection strategies becomes obvious. Predisposition, a triggering fact in the genesis of forest damage, is deemed to be a crucial point for the development of explicit preventative concepts. Identifying circumstances that enhance the probability of damage, illustrates the possibilities and

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limitations of damage prevention. Therefore, the assessment of the predisposition of forest stands and sites facilitates decisions of forest managers, where measures of forest protection should be enforced and monitoring is of high importance. In the given context, damage is defined as some disturbance (e.g. windthrow, snow breakage, bark beetles etc.), which is counter to a specific objective of forest management. Consequently, the term 'danger' represents the potential of disturbing the continuity of different human defined forest functions.

2. Material and Methods

To support foresters' decisions in the course of preventative forest management, an assessment system including numerous parameters has been established, which facilitates the detection of a predisposed stand and site conditions. It consists of a combination of several sub-systems for the assessment of the site and stand related predisposition to abiotic disturbance agents (such as pollution, wind and snow) as well as biotic agents (such as phytophagous wasps, bark beetles, red deer and fungi).

Within the scope of this contribution, the assessment of the predisposition to *Ips typographus* is presented in particular, including first steps toward system verification.

For the present concentrating on Austrian sites, the so-called 'award penalty point systems' (see Speight and Wainhouse 1989 or Berryman 1989) identifies sources of danger either due to natural circumstances or due to human intervention in forest ecosystems.

Based on a comprehensive literature analysis, a checklist of relevant indicators for the predisposition was made up for every single injurious factor (e.g. geological substratum, soil type, geomorphologic characteristics, slope and aspect, water and nutrient supply, tree species composition, stand age, stand structure). Each indicator was assigned to a certain weighting class according to its contribution to the overall predisposition, clearly described in the special literature. Subsequently, the indicators were split into a consistent scale, where specific scores were attributed to every scale level. To illuminate ways of damage prevention, positive and negative signs were attributed to each feature class, representing its danger-enhancing and danger-reducing effects. Impairing factors with overlapping influence orbits were assigned to lower weighting classes in order to avoid false predication patterns. The assignment of scores was oriented on the principal relationship function between the destructive agent and its target, directly or indirectly described in the relevant literature. The assignment of scores and weighting numbers is not the result of a statistical calculation, but of an extensive analysis of the available literature and can thus be seen as an empirical approximation.

Precisely deducing the predisposition of a certain locality, the actual predisposition numbers are summarised and related to a most unfavourable total predisposition amount. The result may be interpreted as the relative predisposition of the assessment unit.

On a given forest management unit, the locally relevant indicators of the checklist may be determined by subjecting the predisposition values of damaged and undamaged sites/stands to statistical analysis (e.g. X^2-tests or discriminant analyses). Thus, site-related indicators with positive signs are dominant at sites with a high natural danger potential, whereas stand related indicators with negative (predisposition decreasing) signs may prevail in other situations. For example, the areas surrounding swamps are at risk from stormthrow.

As site- and stand-related indicators were treated separately, the application of the system allows a mapping of spatial danger spots of forest damage (such as pest infestations), and also supports the planning of future forest management measures.

Since the availability of data-sets may vary significantly among different forest management units or forests administrations, particular emphasis had been put on the

flexibility of the assessment systems concerning the underlying data. Hence, site or stand particularities can be taken into account by changing the respective weighting-numbers or the predisposition points. Indicators of the checklist, whose local importance has been proved to be secondary in the course of a statistical analysis (compare 3.2), may be neglected.

3. Results

In the following section, the results of the literature analysis concerning the predisposing circumstances for the *Ips typographus* are briefly discussed and the process of hazard estimation respectively of system verification is demonstrated. As a detailed citation of all relevant authors for the establishment of the assessment system would go beyond the scope of this contribution, only selected articles are cited. For a comprehensive literature discussion see Führer and Nopp (2001) or Netherer (2000).

3.1 Selected indicators

Referring to the site, four distinct groups of indicators were evaluated as relevant agents of the predisposition to *Ips typographus:* (1) climatic/weather conditions (temperature, precipitation); (2) terrain features (topology, exposure and slope gradient); (3) soil characteristics (type of soil, water supply, periodical wetness); and (4) the site-related predisposition to wind and snow damage.

In Figure 1, the various and complex interactions between the different site-related indicators are reduced to some main pathways in order to discuss the selection of the parameters of the assessment system. On the one hand, the developmental conditions of *Ips typographus* are directly influenced by site parameters, on the other hand, they depend on the vigour status of Norway spruce (*Picea abies*). All agents, illustrated in Figure 1, are interrelated, thus synergisms and antagonisms between them have to be taken into consideration.

Climatic parameters: The success of a complete cycle of development from egg to adult mainly depends on temperature (Merker 1952; Wermelinger and Seifert 1998). As *Ips typographus* will not survive hibernation during its pre-imaginal stages, descendant individuals need to consume heat sums that allow at least the achievement of the post-pupal state. Sites, characterised by thermal conditions leading to early swarming in spring and high developmental rates, facilitate parental breeding and polyvoltinism and are consequently rated as highly hazardous. The climatic situation of a region, especially the amount of precipitation during the vegetation period, the amount of snow and the duration of snow cover during wintertime, influence the site quality for *Picea abies.* Reduced host tree vitality as a consequence of water deficiency is a primary cause of bark beetle infestations.

In this context *soil parameters* (e.g. structure and texture) play an important part. Spruce bark beetle infestations are often concentrated in stands growing on xeric or permeable soils, thus suffering from water stress (Wild 1953; Vite 1984; Berryman 1988; Schopf and Köhler 1995). Dehydration of trees can also result from stagnant soil conditions, gleyification or pseudogleyification of a site. These parameters limit root growth and can be identified both as important factors related to site-related predisposition to *Ips typographus* and to storm damage (Nopp 1999).

Terrain characteristics including topography, site exposure and slope gradient as indicators of a hazard-assessing system, facilitate the synthesis of climatic and hydrologic aspects. Penalty points were assigned to features that are favoured by solar irradiation. Especially south and west

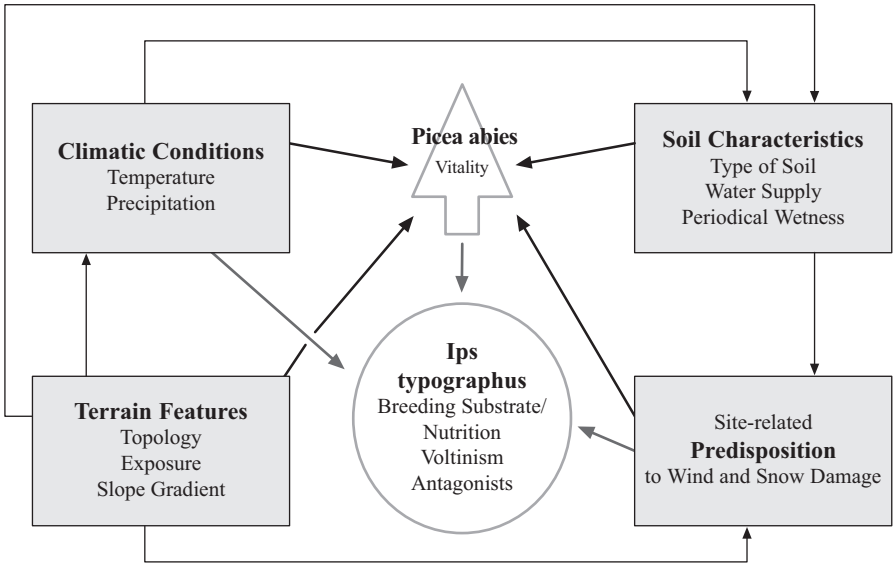

Figure 1. Site related indicators of the assessment system for *Ips typographus*, influencing both the bark beetle himself and its host.

exposed slopes, ridges or plateaux offer supportive temperature conditions to bark beetles (Wild 1953; Schwerdtfeger 1955). Additionally, these locations are often affected by limited water resources. The accumulation of water and nutrients given on valley sites or basins, is rated to be indifferent concerning the predisposition to *Ips typographus*.

Storm damage (and snow breakage) ranks among the main causes of bark beetle outbreaks, for breeding substrate and food is supplied on a massive scale (Bakke 1983; Schopf and Köhler 1995). Frequent windfall enables a persistent high endemic population level and eases the way to mass outbreaks in case of the appearance of additional predisposing factors (Merker 1952). Nopp (1999) highlighted the following factors that indicate an increased site-related predisposition to storm damage:

- *topological features* that favour an accumulation of nutrients and water (e.g. basins, valleys) or high wind speed and turbulence; and
- stagnant *soil conditions*, soil compaction, gleyification or pseudogleyification.

Concerning the assessment of the predisposition of a *forest stand***,** six groups of indicators can be distinguished:

- tree species composition, especially the abundance of *Picea abies*;
- stand age;
- canopy closure;
- quality and intensity of forest management activities;
- criteria concerning the stand vitality status; and
- stand-related predisposition to wind and snow damage.

Forest management affects all stand characteristics, and therefore, its intensity is of high relevance for a forest's predisposition status to the *Ips typographus*. On the one hand, human activities may result in unstable, highly susceptible stands. On the other hand, adequate preventative or curative measures may decrease the probability of pest outbreaks. Consistent

removal of logging residues and salvage cutting were proved to be reliable strategies to avoid mass epidemics.

Forest composition and stand age: *Ips typographus* meets optimised breeding conditions in spruce dominated forests of advanced age (Schwerdtfeger 1955), whereas habitats of important antagonist organisms are limited in such forests. Experience shows a decreasing hazard of infestation with increasing abundance of alternative tree species, especially deciduous trees (Scherzinger 1996). Stands younger than 60 years usually are not affected by *Ips*-attacks, while maturity and overmaturity are factors associated with attacks.

Canopy closure: The more openly stocked a stand, the higher is the amount of solar irradiation, and in consequence, air and cambial temperatures of standing and lying logs. Sunny forest edges or gaps are favoured spots of bark beetle attacks. An abrupt increase of the solar irradiation stream due to a sudden isolation of trees in the course of thinnings or secondary fellings leads to stress symptoms and constitutes an important predisposing fact.

The susceptibility of *Picea abies* to *Ips typographus*-infestations depends on its *vitality status*. However, visible tree vigour indicators are difficult to define. The beetle reacts in a very sensitive way to the health state of its host: Marginally harmed individuals, and trees suffering from acute but reversible damage, seem to be most attractive (Lindenthal and Führer 1993; Scherzinger 1996). Provided that the population density level is high, *Ips typographus* also attacks sound trees.

According to Nopp (1999), indicators of an elevated stand related *predisposition to wind damage* are:

- high abundance of *Picea abies* at the expense of deciduous trees;
- even-aged, single-storied stands;
- inconsistent canopy closure;
- lack of shelter or wind mantle;
- high stand density and lack of thinning in juvenile stages;
- root injuries, stem wounds and damage caused by air pollution;

The presented preliminary model for assessing the predisposition of forested areas to *Ips typographus* consists of 5 criteria of both site and stand level, combining appropriate indicator and weighting classes as demonstrated below (see Tables 1 and 2).

3.2 System verification

The higher the deduced status of predisposition, the higher will be the possibility of severe injury of the respective site or stand. Strongly predisposed stands on sites with marginal danger may be threatened to a lesser degree than less predisposed stands on highly hazardous sites. As the predisposition-related point of view mainly takes into consideration the victim-related pathway of damage, stands may evade harm only because of the (probably random) absence of destructive agents. That clearly indicates that the validity of the system is not always simple to prove. Principally, the distribution-pattern of damaged stands or sites should represent a right-skewed curve with increasing predisposition level. The distribution for undamaged stands or sites would be the other way around.

The absolute and relative frequencies of stands within the classes of geomorphology or within the classes of infestation status (‘infested’ and ‘not infested’) are rather uneven (see Figures 2 and 3).

Stands, stocking on slopes prevail compared with stands on ridges/plateaus or in valleys/basins (Figure 2) and the majority of stands are not infested by *Ips typographus* (Figure 3), which clearly indicates the need for frequency adjustment.

Table 1. Site related components of the assessment system of *Ips typographus.*

criterion	indicator	weighting
elevation [m above sea level]	>1800 1501–1800 1001–1500 501–1000 <500	5
exposure	N NE/E NW/W SE/S SW	4
topography	hilltop/plateau/ridge slope valley/ditch	1
water supply	xeric moderately xeric (moderately) fresh moist waterlogged periodical wetness	3
predisposition to storm throw	low moderate high	4

Table 2. Stand related components of the assessment system of *Ips typographus.*

criterion	indicator	weighting
abundance of Norway spruce	dominant subdominant admixed/single individuals	5
forest age	young growth/thicket polewood mature forest overmature forest	4
canopy closure	densely stocked closed canopy openly stocked/gappy	2
intensity of forest management	low high	2
predisposition to storm throw	low moderate high	4
recent storm damages	yes no	4

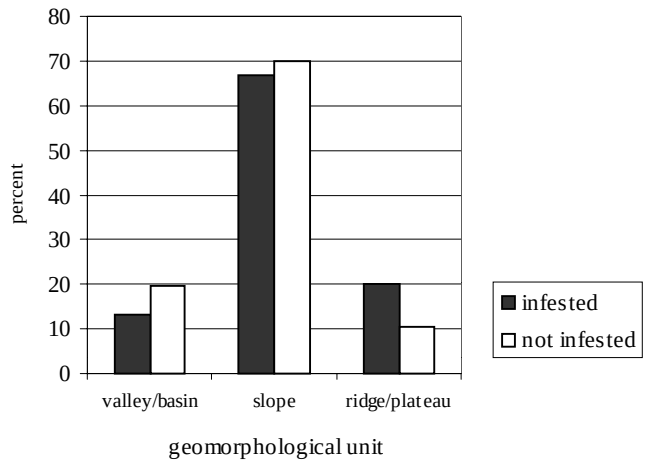

Figure 2. Relative frequency of investigation units in the 3 different classes of geomorphology, separately calculated for the collective of infested and not infested units (investigation area: NP 'Limestone Alps').

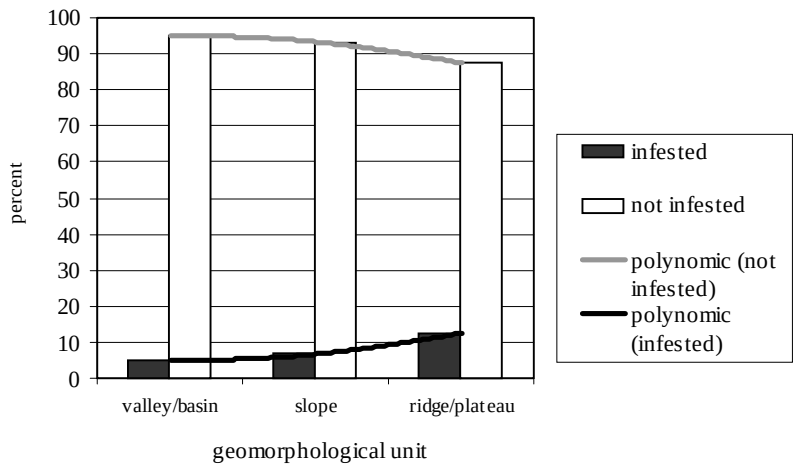

Figure 3. Relative frequency of investigation units in the classes of geomorphology, separately calculated for each geomorphological unit (investigation area: NP 'Limestone Alps').

In order to overcome the unequal frequencies, a re-standardisation was carried out. First, the relative distribution of infested stands over the three different classes of geomorphology was calculated and also the percentage of stands not damaged by the bark beetle was checked concerning the geomorphological indicators. That means, that the collective of infested or of not infested stands was split according to their relative occupancy of terrain classes. Subsequently, these relative frequencies within a given class of geomorphology were added, set at 100%, and compared. Thus, a double percentage was calculated, which represents the relative distribution of stands damaged or not damaged by *Ips typographus* within one terrain unit. Thereby, the selectivity of each single terrain related predisposition indicator could be proved (see Figure 4).

An analogue method was chosen for the comparison of the relative frequencies of infested and not infested stands between the three geomorphological classes: the percentage of

damaged and undamaged stands was calculated for each single terrain class separately and these relative frequencies were summed for the 2 classes of infestation status ('infested' and 'not infested') respectively. The sum was set at 100% again and each percentage of infested stands within a certain terrain class was referred to it (see Figure 5).

Thus, the adjusted relative frequencies are to demonstrate the quality or selectivity of the predisposition indicators.

Applying the complete set of site- and stand-related indicators (compare Tables 1 and 2) to investigation sites in Upper Austria (NP 'Limestone Alps'), specific predisposition numbers resulted for every single investigation point and each predisposition indicator according to the assessment system of *Ips typographus* described above. These predisposition points were

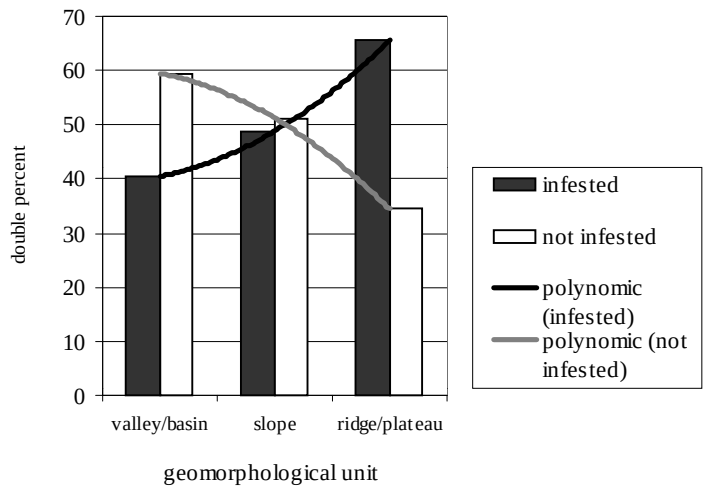

Figure 4. Adjusted percentage of *Ips*-damaged and undamaged stands within defined geomorphological indicator classes in the National Park 'Limestone Alps' (Upper Austria).

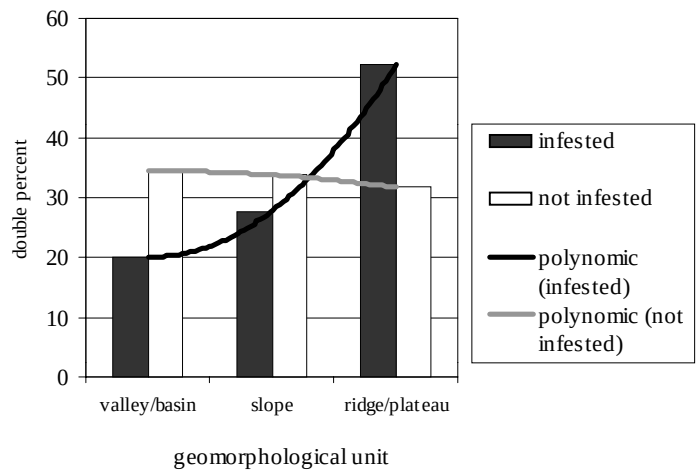

Figure 5. Adjusted distribution of *Ips*-infested and not infested stands between various geomorphological situations in the National Park 'Limestone Alps' (Upper Austria).

summed and referred to a most unfavourable predisposition number. Thereby, relative predisposition numbers could be calculated for each investigation unit. Afterwards, all investigation units were assigned to classes of low (<33%), medium (33–66%) and high (>66%) relative predisposition. The resulting frequencies and functions followed the expected trend (see Figures 6 and 7).

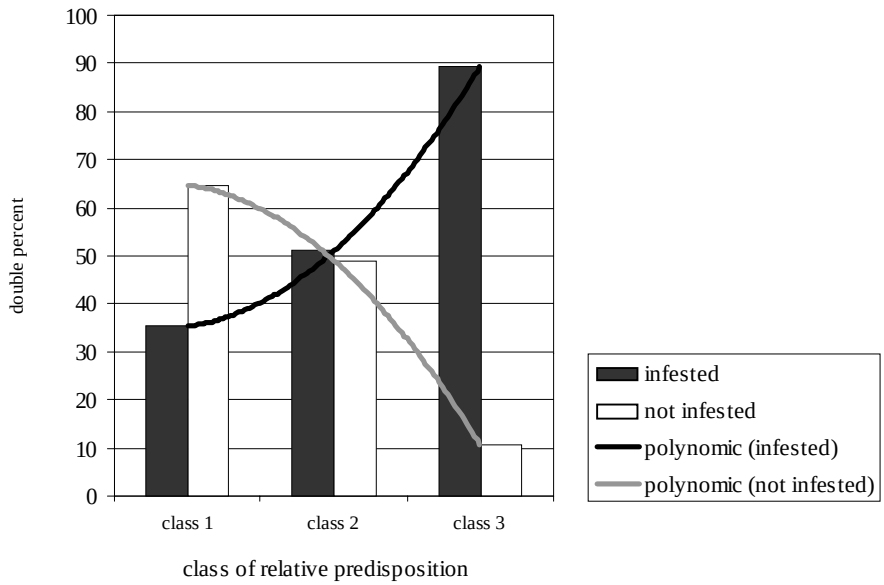

Figure 6. Selectivity of site related predisposition classes (data source: National Park 'Limestone Alps', Upper Austria).

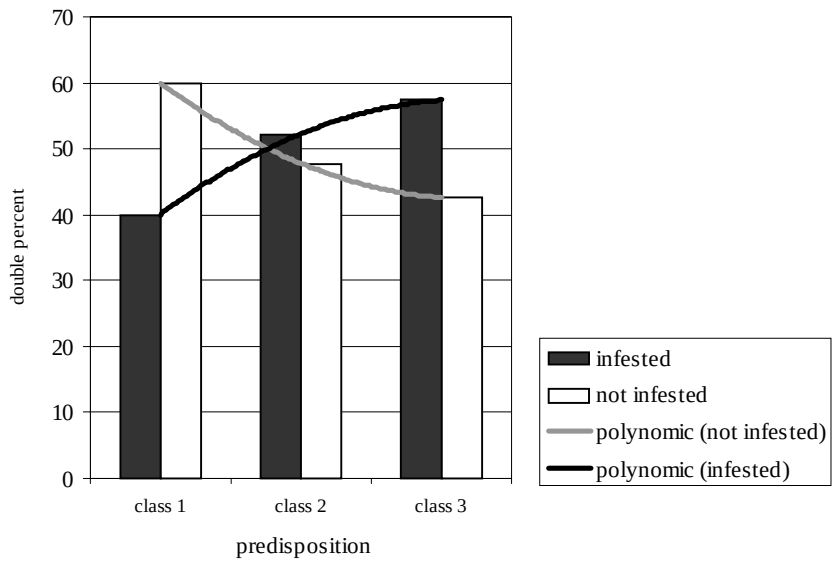

Figure 7. Selectivity of stand related predisposition classes (data source: National Park 'Limestone Alps', Upper Austria).

Discussion

The predication pattern of the predisposition keys, which is the combination of all predisposition indicators, sufficiently corresponds to given facts (infestation history of sites and stands in the National Park 'Limestone Alps'). Especially, the classes of high and low predisposition clearly differentiate infested and not infested localities. Infested investigation units prevail under conditions of high predisposition.

As these results are only first steps in the development and application of the assessment system for *Ips typographus*, further investigation areas should be tested and further calculations should be carried out such as C^2-tests or discriminant analyses.

For the first, the chosen parameters and their combination represent the observed infestation patterns in a satisfactory way, and are thus evaluated as adequate predisposition indicators. Localities, where high predisposition numbers were found, can be seen as focal points of future infestations. Preventative measures of forest protection should be concentrated in these localities. Monitoring of bark beetles should also be carried out.

Principally, the preliminary evaluation results emphasise the quality of the developed assessment system and give rise to further modelling activities.

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A Species-Habitat-Model for the Improvement and Monitoring of Biodiversity in Modern Ecological Silviculture – Capercaillie (*Tetrao urogallus*) in the Black Forest

R. Suchan, and R. Baritz

State Forest Research Station Baden-Württemberg, Freiburg, Germany

Abstract

Modern ecological silviculture in Germany is still lacking quantified parameters to improve and monitor biodiversity. We hypothesize that not only the occurrence of rare species, but also the simple presence of habitat structures at the forest stand and forest mosaic level fulfil the criteria of sustainable biodiversity in managed forests. Because no operational definitions of biodiversity are available yet, a species-habitat model was developed based on the umbrella function of an indicator species, here Capercaillie in the Black Forest region. We found that the Black Forest provides enough potential habitat for the survival of a Capercaillie meta-population (ca. 60 000 ha). Considering the specific habitat affinity of Capercaillie, a framework of structural habitat parameters was transferred into a silvicultural model. Such a species-habitat model provides the methodological basis for: (a) forest managing towards sustainable biodiversity; and (b) the success control of specific silvicultural measures.

Keywords: indicator species, Capercaillie, Tetrao urogallus, local scale, landscape scale, ecological silviculture, species-habitat model, Germany

Forest Management in Central Europe

In contrast to the worldwide situation, forests in central Europe are not threatened anymore by large clearings and/or deforestation. These forests are now managed to become relatively 'close to nature' and to contain a high biodiversity. This clearly contrasts to other forms of land use, such as agriculture. However, no completely natural environments remain today. In

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particular, forests on rich sites have been drastically cleared during the last centuries. The expansion of land for agricultural production as well, as the increased need for natural resources with the beginning of the industrialization epoch, have become the catalysts for change of the cultural landscape. Historical overuse, soil drainage that drastically lowered groundwater tables, spatial disruption of extensive compact forest land, and pollutant deposition, have dramatically changed species composition and forest structure. It was the concept of sustainable silviculture, developed about 200 years ago, that saved the German forests from complete destruction. The establishment of age class forests and large afforestations gradually increased the area of forested land. However, biodiversity in historically devastated forests was assumed to be highest, and probably even higher than in former primary forests (Ammer 1997). Ironically, biodiversity in fairly homogeneous age class forests, which are mostly dominated by one tree species, is low.

Most of today's forests in central Europe are concentrated in the Alps and interior low mountain ranges. Under natural growing conditions, the majority of Europe's landscapes are assumed to be formerly forested, except for a few extreme sites (Ellenberg 1996). Because afforestations through historical forest regeneration programs mainly introduced undemanding coniferous tree species, labile single-species forests developed that are highly susceptible to disturbance (Schlesinger 1996) e.g. through insect epidemics. The problems concerning biodiversity and sustainability of multiple-use have meanwhile been recognized. The principle of ecological silviculture, which now is the main element of most forest programs, offers an effective alternative to increase biodiversity and to protect the forested land. But how can biodiversity be measured?

Monitoring of Biodiversity in Forests

As a consequence of the 'Convention of Biodiversity' in Rio in 1992, and the resolutions of the 'Conference for the Protection of Forests in Europe' in Helsinki in 1993, all signatory states have to give proof of the sustainability of their forest sectors. As a monitoring instrument, six criteria and 27 indicators were agreed upon and formally accepted at the 'first expert level follow-up meeting' in Genf in 1994. Biological diversity is one of the six criteria that should be improved in managed forests, or at least maintained. Despite the definition of five indicators for the assessment of biodiversity, it is not yet successfully integrated into the monitoring of sustainability in the management of forest ecosystems (Ellenberg 1997).

Silvicultural measures in modern ecological forest programs do not automatically maintain or improve biodiversity, but it is sometimes assumed that they do. Successful breeding or site establishment of an endangered species is often the only direct controlling instrument to monitor the ecological sustainability of the current management. The list of indicators for the development of biodiversity, defined during the Helsinki follow-up process, only contains indirect parameters that represent structural aspects of biodiversity on a very coarse scale (see Ellenberg 1997). Stand-level parameters are completely missing.

Currently, there are no clear and complete concepts to record and monitor diversity. Because forest stand inventories are the main source of information at the stand level, this deficit has become one of the main problems in the current discussion about modern inventory designs (Gadow 1999). There is a growing demand to introduce new parameters that describe stand structure and biodiversity (Füldner 1995). Most of the suggested modifications in forest inventory are limited to stand level approaches (Gadow 1999). The requirements to sustainably maintain and/or improve biodiversity in the context of interdependent biocoenoses on different temporal and spatial scales are not fulfilled yet. For

example, parameters of forest structure in the habitat of relatively wide-ranging ungulates cannot be defined just on stand level because of their large home ranges (up to several hundred hectares). At the level of sub- and meta-populations, areas of more than 1000–10 000 ha have to be analysed. In silviculture, which is the main management tool in practical forestry, measures are concentrated at the stand level. The decision making process is based on results from forest stand inventories. It still remains an open question, as to how ecological principles and aspects of species protection (both essential components for the development of suitable habitat structures in a complex living environment) can be incorporated into silviculture.

Modern Ecological Silviculture in Germany

After centuries of restoration of, (1) historically overused forests, and (2) labile forests caused by a purely economical forest management, more and more focus is concentrated on nature protection and management alternatives that consider the importance of forests to be the last remaining large and relatively compact ecosystems with a high degree of 'naturalness' (Weiger 1997; Späth 1992). Usually, the ecological analysis of present forests is limited to comparisons between intensively managed forests, described as monotonous forests with a minimum of structures, and completely unmanaged forests, which are described as being rich in structure with high species density (Held 1992; Hnatyshyn 1993; Scherzinger 1996). Such a simplification is not necessarily correct because similar amounts of species and species densities can be found in managed as well as in unmanaged forests (Ammer 1997). However, number of endangered species alone is not a suitable parameter for ecological evaluations of silvicultural methods. Ellenberg (1997) emphasizes that such an approach is incomplete in terms of clear definitions and for biological as well as statistical reasons.

The abundance of a species is determined by a complex of factors depending on site factors, all other faunistic and floristic members of the biocoenosis, and anthropogenic influences. The simple occurrence of a (protected, endangered) species in an ecosystem cannot be used as an orientation for management practices without considering this complex of factors (Edwards and Scott 1994). Species occurrence does not necessarily allow conclusions about the habitat quality in the context of nature protection, and the absence of a protected species in a certain forest does not automatically imply the lack of suitable habitat. Chance also plays an important role in the process of site establishment.

Another theory that is often used to support modern silvicultural concepts, is the expectation that nature protection is an automatic consequence of ecological sustainable silviculture (Scherzinger 1996). Such a process cannot be taken for granted until operational criteria and indicators are available to monitor the success of silvicultural measures aimed to protect endangered species or increase biodiversity in general.

The basic principles of ecological aspects in forest management have been incorporated into new forest programs with ecological silviculture as the main component (e.g. MLR Baden-Württemberg 1992). *Ecological silviculture* can be defined as a strategy of forest utilization which considers forests to be ecosystems where management has to be based on ecological site conditions and natural vegetation dynamics in climax systems. The main objective is to establish stable and resilient forests, where susceptibility to storm and snow damage, insect pests and soil degradation is minimal and where environmental factors allow stand development in natural regeneration systems (Table 1). In consequence, traditional age class forestry will become drastically reduced in German forestry (MLR Baden-Württemberg 1992; Mosandl 1993).

Table 1. Characteristic elements related to biodiversity in modern ecological silviculture in Germany.

basic elements related to diversity	parameter	general objectives
silvicultural properties	***examples***	
multi-species forest stands →	proportion of species	improvement of - stability - site condition - "naturalness"
natural regeneration →	% cover	
prolonged rotation period →	age class distribution	
multi-layered canopy →	number of layers	
selective cutting →	basal area of trees	
framework for planning and management intensity		
biotope mapping and conservation	no structural or species-related parameters defined	conservation of - rare forest stands - genetic reserves
network of forest reserves		
mapping of forest functions		
site mapping		improvement of - habitat diversity
accompanying programmes		
snag and woody debris programme		protection of - rare species - rare forest sites
road- and stream-side programmes		
forest edge programme		

Deficits in Ecological Silviculture Concerning Biodiversity

Continuous timber supply, sustainability of woodland area and timber stocks have been well-established principles in German forestry for more than 200 years. Within the context of sustainability and biodiversity, it is widely accepted that modern ecological silviculture can preserve and improve the ecological value of forest ecosystems (Thomasius 1992; Mlinsek 1993; Volk 1993; Weidenbach 1993).

From a wildlife perspective, these modern forest programs are still facing substantial 'ecological' deficits if elements of species protection and biodiversity are also considered:

1. Decline of endangered species (intensification of central European forestry has endangered most of the larger forest birds (Waliczky et al. 1997)).
2. Species protection only refers to species individuals and to habitat condition on stand level. Regional aspects (degree of fragmentation, mosaic of successional stages/stand growth stages) are usually excluded from the development of nature protection and forest programs and activities.
3. No precise information is available concerning habitat space required to realize measures for habitat improvement (this data is necessary to address active silvicultural programs to suitable sites/areas).
4. Protection of biocoenosis and food chains is usually lacking in species and area protection programs (however, this relation is often only poorly understood).

These deficits are fairly well-known by silviculturists and were assumed to be compensated by the use of 'red data books'. Because the use of such lists of endangered species is still lacking applicable temporal and spatial species-related information, the *selection of target species and indicator species* has gained importance (Ellenberg 1997; Vogel et al. 1996; Altmoos 1997; Flade 1994). Concerning nature protection and species diversity, only conservative (indirect) measures have been realized so far, such as area protection programs (e.g. declaration of forest reserves; however, without a standardized research program of

species protection measures). No direct concepts/conclusions for practical forestry exist except the imitation of forest structures similar to those found in natural forest reserves under the exclusion of management influence.

With this paper, we want to show that the use of *habitat parameters of indicator species* offers an operational silvicultural tool to improve and monitor biodiversity in intensively managed forests on stand as well as on district level.

Spatial Scale

Several studies have shown that environmental and anthropogenic factors on district and regional level have substantial influence on the survival of birds and larger animals in forests (Hinsley et al. 1995; McGarigal and McComb 1995). Therefore, not only the average home range of a species individual has to be considered (e.g. 100 ha for Capercaillie), but also the minimum area required for the survival of a meta-population (critical habitat; usually a composite of sub-populations including habitat/biotope links). Also, important key species (indicators, umbrella species) can only survive on large territories (Hart and Horwitz 1991). Habitat requirements of meta-populations can best be investigated from bottom-up aggregation of small-scale stand and district level structures in combination with landscape properties mapped on a larger scale. Currently, there are no systematical concepts to monitor landscape changes and its effects on biocoenoses (König 1996). Measures to protect certain species or measures that would improve biodiversity as a whole have to consider all spatial scales that contain influential factors relevant for the survival of individuals as well as meta-populations. Consequently, a prerequisite for the habitat concept of indicator species is the precise definition of *scale* (Figure 1).

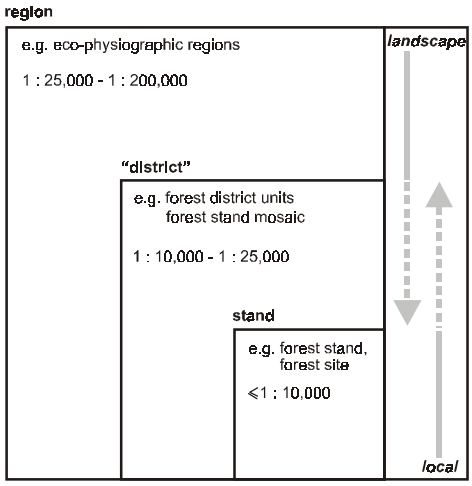


Figure 1. Spatial scale necessary for the development of silvicultural measures to improve biodiversity.

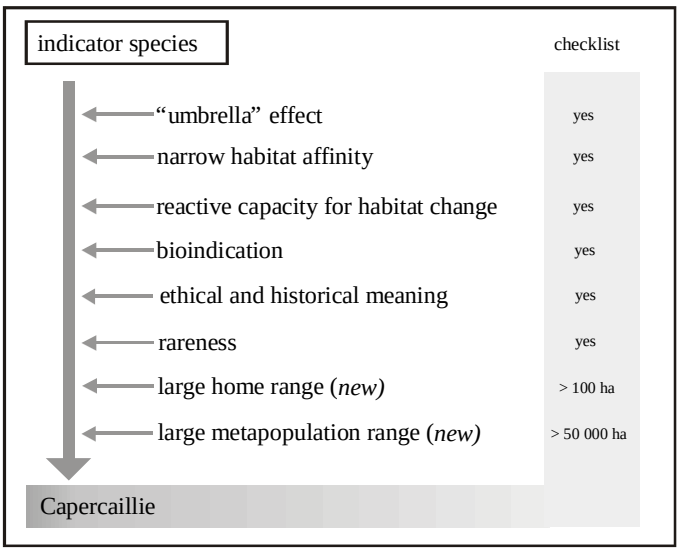
The list of parameters in Table 1 clearly shows that silvicultural measures in forestry are concentrated at the local scale – in the following text referred to as *stand level*. With silvicultural parameters, structures in forest stands (e.g. stand texture, species composition in

the regeneration layer, etc.) can be quantified. The map scale for the stand level (patch size = 1–100 ha) is usually <= 1:10 000 (Figure 1). However, some structural parameters (habitat properties) important for fauna and flora are not included yet in stand-level silviculture (e.g. abundance of dwarf shrubs, density of ground vegetation, etc.). They have to be introduced through wildlife- and diversity-oriented modifications. No complete evaluation of silvicultural measures towards biodiversity is possible if quantitative concepts at larger scales are still lacking. At the *district level* (map scale 1:10 000–1:25 000; patch size = 100–1000 ha), new parameters and also modifications of stand-level silvicultural parameters are necessary to describe the quality of forest as habitat (e.g. based on the mosaic of stand level parameters, patch size and patch dynamics, length of edges and neighbourhood relations). Preliminary evaluations for the Black Forest (*regional level*) have shown that characteristic structural elements at a larger scale (1:25 000–1:200 000; patch size >10 000 ha) are also important in order to assess the potential habitat range of wildlife especially within eco-geographically homogeneous landscapes. Examples for parameters describing structures on regional level are macroclimate, topography, fragmentation and land use type.

Indicator Species

Population density, metabolic condition or physiological capacity of indicator species can represent distinct environmental conditions and developments, which would be very difficult and expensive to determine through alternative methods (Altmoos 1997). Because forest measures are implemented at different scales (stand and district level), and because important environmental and anthropogenic factors relevant for species survival can be addressed to the landscape scale, specific requirements for the selection and usefulness of indicator species in forest management result (Table 2).

Table 2. Factors relevant for the selection of indicator species for high biodiversity – Capercaillie *as an example.*



Only the combination of all the factors described in Table 2 can fulfil the requirements for an indicator species, which does not simply stand for certain habitat parameters, but also for other important factors relevant for high biodiversity. The assessment of the potential habitat space for an indicator species on landscape scale is important, because availability of optimal habitat structures and requisites differs substantially among landscapes (Flade 1994). Additionally, only at the landscape scale, can the MVP-area (area required for a minimum viable population size) for species with large home ranges be found and designated. Knowledge about the abundance of indicator species at the landscape scale also helps to assess large-scale habitat structures important for the designation of priority areas.

It can be concluded that Capercaillie (*Tetrao urogallus*) fulfils all factors listed in Table 2, and can, therefore, function as a valid and helpful indicator (Storch 1994).

Capercaillie

Capercaillie (*Tetrao urogallus*) is widely accepted as a symbol of high structural diversity and species richness in montane and upper montane mountain ranges in central Europe (Adamic 1987; Valkeajärvi and Ijäs 1986; Helle et al. 1989; Moss et al. 1991; Baines et al. 1995; Beshkarev 1995; Storch 1995).

Table 3. Stand-level structural parameters used to characterize the habitat of Capercaillie

habitat parameters	optimum	authors
canopy density [percent coverage of the canopy]	50–70%	Winquist (1993), Franceschi and Bottazzo (1991), Storch 1993, Moss (1994), Schroth (1994), Klaus (1997)
cover of bilberry	>75%	Koch (1978)
	>20%	Storch (1993), Schroth (1994), Moss (1994)
stand age	>35 cm BHD	Eiberle (1976)
	>100 years	Schröder (1974)
	>70 years	Rolstad und Wegge (1987)
cover of ground vegetation	>60%	Schroth (1994)
edge length	-	Schroth (1994), Stein (1974)
tree species	1. pine	Wilhelm (1982), Lindén (1989), Sjöberg and Lindén (1991), Rodriguez and Obeso (2000)
	2. fir	Jacob (1987), Kristin (1990), Storch et al. (1991)
	3. beech	wilhelm (1982), Jacob (1987), Kristin (1990), Storch et al. (1991), Lieser (1996)
	4. spruce	Almasan (1970), Heinemann (1989)

It was already shown in many studies that the habitat of Capercaillie can be described using specific structural parameters (Table 3). These results also emphasize the fact that small-scale habitat structures are closely integrated into the patch and land use mosaic at a landscape scale (Rolstad and Wegge 1989; Menoni 1994).

The Black Forest represents a densely forested mountain range in southwestern Germany, where parts of the montane areas are still inhabited by Capercaillie. Because of the large distance to other landscapes with populations of Capercaillie, and because of the intensive land use and fragmentation surrounding the Black Forest, the remaining populations of

Capercaillie are fairly isolated and assumed to belong to one meta-population. In 1993 and in 1998, the abundance of Capercaillie in the Black Forest was investigated in large monitoring projects. The results show that Capercaillie is concentrated in several large clumps, each representing a sub-population (Suchant 1998). Additionally, the potential habitat space at a regional level was determined in order to forecast future population dynamics (Suchant 2000). The Black Forest is one of the very few sanctuaries, where the population size of Capercaillie (380 males) is assumed to lay above the MVP (minimum viable population) despite alarming decreases in abundance during the last 3 years.

At stand level, a total of 20 000 ha forest land in the Black Forest was mapped and evaluated. The results show that optimal grouse habitat is highly fragmented and covers only 20–40% of the forest land. Based on the habitat affinity of Capercaillie (comparison of Capercaillie occurrence and habitat character), structural parameters with best fit on local and district level were selected.

Although Capercaillie has been eliminated in many other regions (or in small segregated population densities below MVP), *silviculture creating optimal habitat* would still be expected to maximise biodiversity similar to areas, where the occurrence and expanding population of Capercaillie indicates the success of silvicultural measures.

Box 1. Indicator hypothesis for biodiversity in forest environments

Silviculture aimed to improve habitat conditions suitable for the survival of indicator species (here: Capercaillie) maintain and/or create maximum sustainable biodiversity in specific forests (here: montane forests of central European mountain ranges).

Species-Habitat Model

Steering silvicultural measures towards habitat improvement for indicator species is expected to support biodiversity (Thomasius and Schmidt 1996; Scherzinger 1996). In order to completely fulfil this objective, a model is needed that links together habitat parameters at various spatial scales (forest stand, forest stand mosaic – ‘district’, region). The objective for the development of such a model is to:

- improve habitat conditions for the indicator species;
- develop silvicultural measures; and
- allow screening of management effects by forest inventories.

Because the populations of most endangered umbrella species cover more than one spatial scale, structural parameters typical for the habitat of indicator species have to be described at all scales involved. *Scale, parameters of habitat structure* and *operational silvicultural measures* are the main components of the *species-habitat model* suggested here.

Some of the most important measures of ecological silviculture are listed in Table 1. However, they are only defined at a local scale, and not all of them are necessary parameters for the indicator species (= Capercaillie) habitat. On the other hand, some important parameters (e.g. density of ground vegetation) are not contained in the list of common silvicultural parameters and measures. Both, selected parameters typical for the ecological silviculture programme as well as additional structural parameters required for optimal grouse habitat have to be added to the model. The method is described in Figure 2.

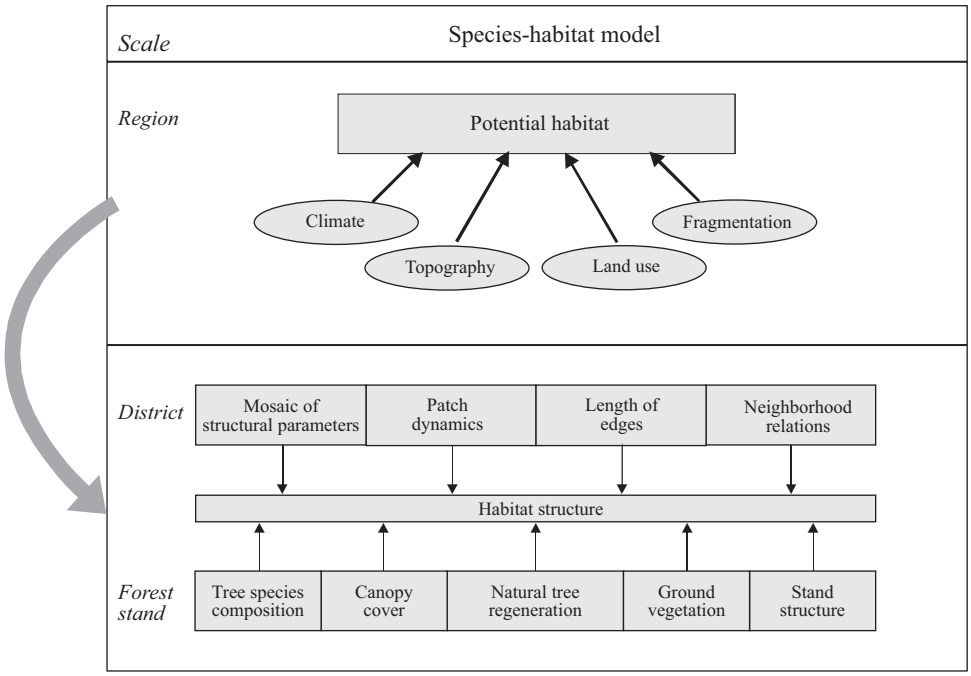


Figure 2. Definition of 'habitat parameters' in an indicator species-habitat model.

An example for a *species-habitat model for Capercaillie* is presented in Figure 3. The list of habitat parameters in the model was shortened in order to allow a quick overview. All habitat parameters were defined and quantified for all three spatial scales. The scientific framework for the definition of the habitat parameters consists of an expert system derived from:

a) an extensive literature review including the results of radiotracking research;
b) habitat analysis of 3 test areas in the Black Forest (20 000 ha);
c) landscape analysis of the Black Forest (total area 600 000 ha, woodland area 400 000 ha) using GIS;
d) monitoring of Capercaillie at the local as well as at the landscape scale.

In the first step of the model, the potential habitat area at the *regional level* is calculated. The main spatial parameters are altitudinal zonation of the Black Forest (= representating macroclimate, topography and vegetation zones), forest patch size, vegetation community, and fragmentation (complex index based on distance between suitable forest patches, road density, land use types). The potential landscape habitat for Capercaillie in the central European mountain ranges can be characterized as large forested areas (>100 ha) in the higher elevations (>1000 m), which are dominated by conifers. From the landscape analysis of the Black Forest, 57 000 ha were found that fulfil these criteria. In this area, protection concepts and silvicultural measures can be implemented in a sustainable manner on a long-term basis. All forest patches less than 2 km distance from the forest core area were included, if they were not cut off by major traffic lines or other major infrastructural features. In the case of larger distances to the next forest patch, biotope links for grouse have to be planned and implemented.

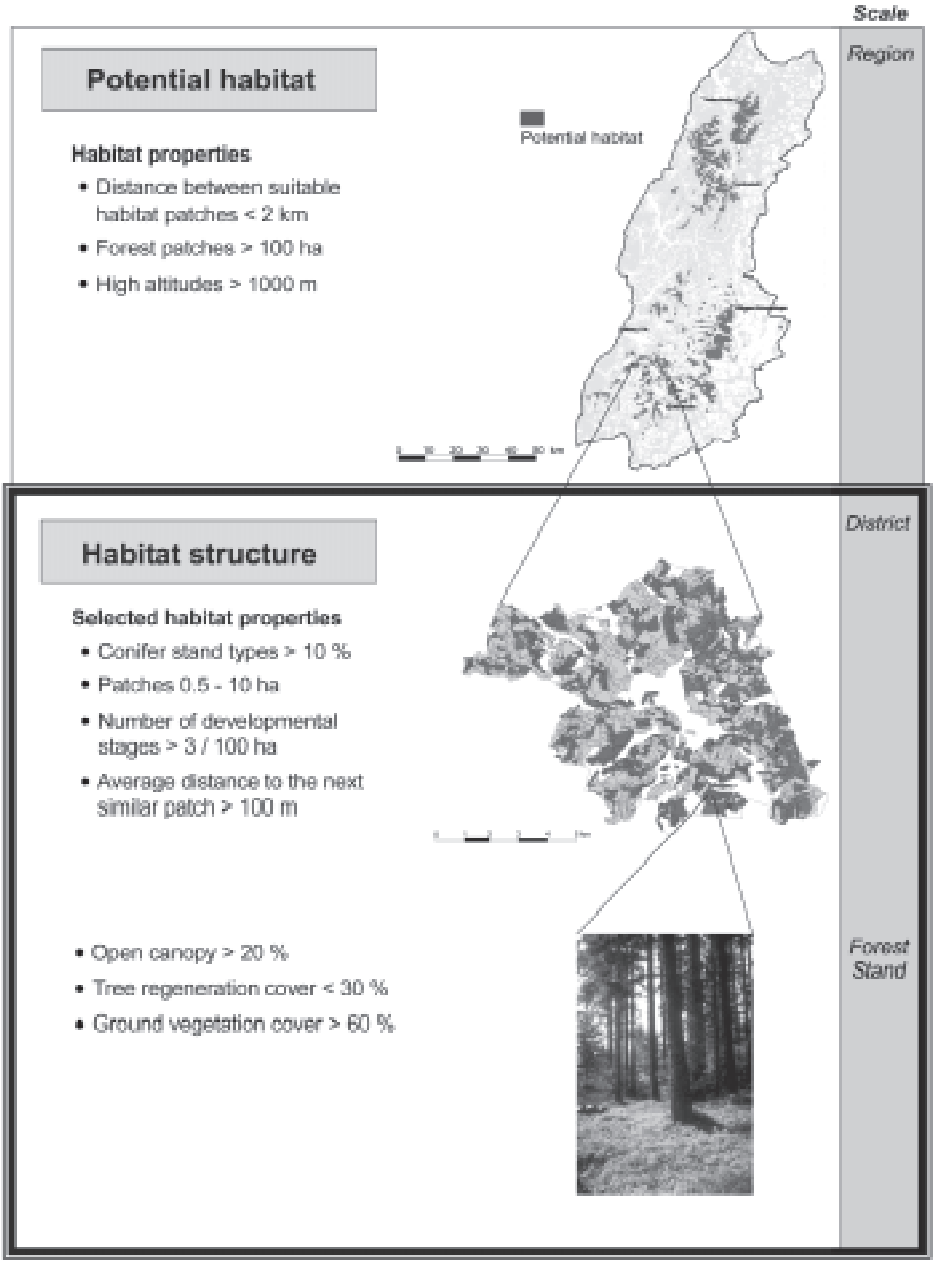


Figure 3. Species-habitat model, realized for Capercaillie.

The potential landscape habitat of 57 000 ha slightly exceeds the calculated habitat area for a MVP (50 000 ha: 500 individuals with an average home range of 100 ha). It can be concluded that the regional ecological landscape conditions of the Black Forest fulfil the habitat requirements of a stable Capercaillie population, provided that the habitat requirements at the local and district levels (compare below) are also fulfilled. If the potential habitat area of a certain region does not equal or exceed the required area for MVP, measures aimed to protect

small isolated populations or to reintroduce an extirpated species would not be successful.
It can be concluded from the current literature on meta-population dynamics of Capercaillie (Storch 2000), that within a potential habitat (landscape), between one-third and one-half of the area has to be optimal habitat. Otherwise, the distance between essential habitat components (e.g. distance between forage grounds and escape cover) is too large and would increase the susceptibility to predation, energy loss during foraging, etc. In connection with the results from the habitat mapping in the Black Forest (ca. 20 000 ha), at least 30% of all forest stands within a district unit can be considered to fulfil the habitat requirements of Capercaillie in order to guarantee the survival of the population (see Table 3). This threshold would increase with increasing stress and with a population size that would fall below the critical MVP.

The habitat requisites of Capercaillie at the *stand level* are listed in Table 3. In areas inhabited by Capercaillie, forest stands with more than 50% stand area covered by coniferous trees with open canopy structure (such as Scots pine) were always found. Sites with dense proportions of the ground vegetation (summer habitat) are also required as well as areas with sufficient, but not too dense, conifer regeneration (winter habitat). The presence of a certain proportion of stand level characteristics alone does not represent optimal habitat structures, if the mosaic of stands lacks structural heterogeneity (presence of old-growth patches along inner forest edges as roost sites, etc.).

At the *district level* (forest stand mosaic) of areas inhabited by Capercaillie, the following mosaic characteristics were found. At least three different developmental stages are required within 100 ha (regeneration stage, old growth in the decompositions phase, etc.). Additionally, more than 10% of the regional mosaic of forest stands has to consist of conifer-dominated stand types, which can be clumped in patches of 0.5–10 ha size. In order to fulfil the requirement of a heterogeneous mosaic, the distance between similar patches is at least 100 m. The length of edges should be longer than 1km/100 ha. These thresholds still required further evaluations because such a mosaic is typically found in Black Forest areas caused by the specific ownership structure and silvicultural tradition.

With this model, objectives for the development of species protection concepts, environmentally oriented forest programs and silvicultural measures can be derived on the basis of measurable field parameters. These parameters are mostly part of the regular forest inventory and can be assessed without extensive small-scale habitat mapping. The planning of silvicultural measures to improve the habitat condition for the indicator species can, therefore, be incorporated into the regular forest management. Information about the suitability and success of implemented measures can be assessed either from repetitive habitat mappings or from continuous forest inventories. This methodology, thus, provides for an environmental monitoring of silvicultural measures.

Conclusions

Whether or not a specific area actually provides the suitable habitat for Capercaillie, depends on the structure and vegetation composition of the forest. Most activities towards species protection focus on habitat protection and habitat restoration at the forest stand level. It cannot be stressed enough that the landscape scale is also important if aspects of population ecology are to be considered in order to steer the success of silvicultural measures in the context of species protection and biodiversity. Therefore, the empirical species-habitat model suggested here, distinguishes between the local scale of individual forest stands, and the landscape scale (so-called district level and regional level) of the mosaic of local structures and habitat fragmentation.

The data basis consists of the mapping of stand-level habitat structures for Capercaillie in three test areas throughout the Black Forest (20 000 ha total). Regional studies investigating the habitat affinity of Capercaillie as well as results from an extensive species census were included to *develop the species-habitat model aiming to introduce operational habitat parameters into ecological silvicultural programs and forest inventories*. On the basis of the high indicator value of Capercaillie for species-rich forests with a wide variety of structures and niches, the presence of Capercaillie habitat structures can be assumed to represent high levels of biodiversity in managed forests.

The fundamental framework of the species-habitat model is the selection of an indicator species for specific habitat structures. A suitable habitat contains a multitude of habitat structures that are suitable for many other forest species. With Capercaillie, such a species is available for montane and upper montane zones of central European mountain ranges as well as for boreal forests. Before silvicultural concepts, which are aimed to improve the habitat of the indicator species, can be implemented, the potential habitat for a minimum viable population (MVP) at the landscape scale must be available. Otherwise, measures to improve the habitat: (a) would counteract natural dynamics; (b) would be very expansive; (c) could not guarantee the survival of the endangered indicator species; and (d) would lack a controlling instrument. A species-habitat model was derived to combine the landscape potential with structural parameters on the local scale. Such a model lists quantified structural parameters at the local and landscape scales, which are related to the habitat of Capercaillie. The specific habitat parameters can then be introduced and realized in silvicultural concepts aiming to restore and improve richness of structures and species in managed forests.

No other land use type than forest exists in central Europe that has comparable potential for the survival of animals at all trophic levels. However, the ecological effects of forest management concepts are difficult to measure. Consequently, the fulfillment of Helsinki criteria related to the improvement of diversity in managed forests has no systematic basis. Biodiversity is still thought to be a by-product of ecological silviculture. We propose a species-habitat model on the basis of an extended indicator concept for ecoregions (here: Black Forest). Such a model can provide an important tool to maintain, improve and monitor diversity in intensively managed forests. Careful selection of an indicator species and precise information about the habitat requirements at different spatial scales relevant for the survival of species individuals and whole populations are the basic requirement for such a species-habitat model.

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Timber Production and Plant Biodiversity Conservation in a Costa Rican Rain Forest: an Experimental Study and its Lessons for Adaptive Sustainability Assessment

Bryan Finegan[1], Diego Delgado[1], Marlen Camacho[1] and Nelson Zamora[2]

[1]Tropical Agricultural Centre for Research and Higher Education (CATIE), Turrialba, Costa Rica
[2]National Biodiversity Institute (INBio), Santo Domingo de Heredia, Costa Rica.

Abstract

Progress towards sustainable forest management in the neotropics will eventually require greater emphasis on monitoring and an adaptive approach, for which baseline data on management effects on fundamentally important plant community characteristics are still required. During the first decade following intervention, a Costa Rican rain forest appeared resilient and productive, although mortality rates rose following silvicultural treatment. Intervention did not affect floristic diversity, but abundances of lianas and some non-commercial tree species were reduced. As in any forest, precaution and best practice can reduce some management impacts on plant biodiversity, and can be evaluated by input and process indicators. Some outcome indicators of floristic change, necessary for adaptive management, are costly to evaluate, and the case study casts doubt on the use of structural indicators as surrogates for floristic ones. Permanent sample plot protocols modified as in the case study, in combination with a focal species approach, are suggested for monitoring. Focal species would have priority if the robustness of floristic diversity is confirmed by further work. Policy and institutional mechanisms to make monitoring possible are urgently needed, and attributes of forest types (limited area, unusual characteristics and degree of threat) and management operations (type and intensity of intervention) should also be used in setting priorities for monitoring.

Keywords: Criteria and Indicators, logging, silviculture, sustainable forest management, Costa Rica

Alain Franc, Olivier Laroussinie and Timo Karjalainen (eds.)
Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level
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Introduction: the Status and Nature of Sustainability Assessment in the Neotropics

Willingness and capacity to implement sustainable forest management (SFM) in the neotropics are growing. Forest certification is increasingly being sought, with 34 forest management units (fmu) with natural forest certified in Mexico and Central and South America (as at January 31 2001). In addition, Criteria and Indicators (C&I) sets for the fmu level are under development through three multinational or regional processes (ITTO; the Tarapoto Proposal of Criteria and Indicators for Sustainability of the Amazon Forest; and the Central American Lepaterique Process) and a number of national initiatives. All the aforementioned Standards conceive ecological sustainability largely in terms of the reduction of management impacts on the forest ecosystem by the clearly indispensable application of 'best practice', and set sustainability assessment in a framework of input and process indicators (see definitions in Lammerts van Beuren and Blom (1997)). This essentially precautionary approach may be politically necessary as SFM is considered unproven by many (Noss 1999) and because widespread destructive logging persists in the neotropics. The implementation of SFM in terms of best practice and precaution would in any case be an enormous step forward, but the attention being paid to the monitoring of the *outcomes* of the forest management process is nevertheless insufficient. National-level policy and institutional mechanisms to ensure that monitoring is relevant, feasible, efficient and effective do not exist. In addition, Standards are usually vague regarding what to monitor, how, and *why*, often compounding this problem by establishing the existence of monitoring programmes as an indicator of sustainability, but not the use of the information produced by monitoring (e.g. in ITTO 1999). Why is monitoring necessary? Because the occurrence, magnitude, direction and significance of changes in key indicators of ecological sustainability should be known (Ferris-Kaan and Patterson 1992). This knowledge can make management adaptive, and the argument that 'natural resource management can only be sustainable if it is adaptive' is persuasive (Holling and Meffe 1996; we recognize that good forest managers adapt intuitively – but the complex environmental components of modern SFM necessitate formal monitoring by trained personnel). What should be monitored? There is not even consensus for temperate or boreal forest (Noss 1999), and needs and objectives are likely to vary between forest types and management regimes. Components of tropical rain forest communities such as birds and butterflies possess the attributes required of indicators and their responses to disturbance are relatively well-documented, so that their monitoring could be implemented where relevant. This is not the case, however, for the fundamentally important plant diversity component, which remains poorly studied in logged or managed neotropical lowland rain forest (Johns 1997, Webb and Peralta 1998). For this latter reason, the following section of this paper focuses on results of research in lowland tropical rain forest of northeastern Costa Rica dominated by *Pentaclethra macroloba* (Fabaceae/ Mimosoideae). Parallel studies at one site of aspects of forest stand dynamics and timber production on the one hand, and the composition and diversity of the vegetation on the other hand, are emphasized for two contrasting silvicultural regimes. This approach permits analysis of tradeoffs between production and conservation and its holistic nature is appropriate to the provision of information for the holistic process of sustainability assessment using C&I. Informal comparisons of the characteristics of the managed forest are made with those of similar but undisturbed forest. In the final section, we draw on these results in highlighting aspects of plant diversity conservation in managed forests and its assessment and monitoring using C&I.

Case Study

Emphasis is given to the results of a silvicultural experiment at Tirimbina Rain Forest Centre, Sarapiquí Canton, Heredia Province (10°24' N, 84°06' W) at an altitude of 180–200 m.a.s.l. We also use data from plots in undisturbed forest at Corinto Farm, Pococí Cantón, Limón Province (10°13' N, 83°53' W), located between 235 and 345 m.a.s.l. Both study sites have low fertility acid soils and hilly topography.

A full description of site conditions and the silvicultural experiment at La Tirimbina is provided by Finegan and Camacho (1999). The originally old-growth forest was high-graded over the period 1960–1989. A 540 m x 540 m (29.16 ha) experimental area was placed under management for the sustainable production of timber in 1989. Timber was harvested at a low overall intensity (10.1 m^3 ha^{-1}) from the whole area in 1989 and 1990, using reduced-impact logging (RIL) techniques. The area was divided into nine 180 m x 180 m (3.24 ha) plots for the application of post-harvest silvicultural treatments. Three different silvicultural regimes were implemented under a complete randomised block design (three replicate plots per silvicultural regime). The first was the timber harvest with no subsequent intervention, referred to hereafter as the 'log-and-leave'. The second was applied in 1991 and involved a refinement and subsequent liberation of individuals determined to be potential crop trees. This treatment is hereafter referred to as the 'liberation/refinement'. The third regime is not discussed in the present paper, as full sampling of plant diversity was not implemented there. At La Tirimbina, stand dynamics for all trees ≥ 10 cm d.b.h. were monitored in a square 1.0 ha permanent sample plot (PSP) in the centre of each 3.24 ha treatment plot (Finegan and Camacho 1999) (d.b.h. = 1.3 m, standard procedures being used for relocation of the point of measurement in the case of e.g. buttressed trees: this size-class is hereafter referred to as the overstorey). The three 100 m x 100 m (1.0 ha) plots in undisturbed forest at Corinto were situated around a 30 ha experimental management area and were separated from disturbed forest by distances of at least 40 m. The same techniques for the enumeration of the stand ≥ 10 cm d.b.h., fully described by Finegan and Camacho (1999) and Finegan et al. (1999), were used at both sites. The understorey was sampled at La Tirimbina only, beginning in 1994. Eighty permanent square subplots of 5 m x 5 m were distributed randomly within each 1.0 ha PSP belonging to each of the log-and-leave and liberation/refinement treatments. Following A.H. Gentry, individuals ≥ 2.5 cm d.b.h. of all plants rooted within the 5 m x 5 m subplots were sampled, including all woody plants, palms, lianas and robust herbs such as *Heliconia* spp. Diameters of lianas were determined at the thickest point of the stem, but we differed from Gentry in sampling palms only when their stems exceeded ≥ 2.5 cm d.b.h., excluding leaf petioles which reached this diameter range. Definitive identifications to species, in both size classes, were given by Nelson Zamora, on field visits or by examination of voucher specimens. Finally, analysis of variance was used to investigate effects of different silvicultural regimes on parameters of stand dynamics and plant biodiversity in the formal experiment at La Tirimbina. Subjective comparisons of forest characteristics at La Tirimbina were made with those of undisturbed forests at Corinto and nearby La Selva Biological Station (Lieberman et al. 1985, 1996, Lieberman and Lieberman 1994).

In 1993, three years after the timber harvest and two years after the application of the liberation/refinement treatment, mean basal area at La Tirimbina was within the old-growth range of 21.4–29.9 m^2 ha^{-1} in the log-and-leave plots (≥ 10 cm d.b.h.; old-growth data from La Selva in Lieberman and Lieberman 1994, Lieberman et al. 1996, and from Corinto), reaching 82% of the old-growth maximum by 1998. On the other hand, basal area in the liberation/refinement plots remained below old-growth values throughout the study, reaching 67% of the old growth maximum in 1998. In contrast to basal area, stand density was within

the old-growth forest range of 418–530 trees ha^{-1} under both treatments throughout the period of study, mean values increasing markedly in both log-and-leave and liberation/refinement plots and surpassing the upper limit of the published old-growth range (Lieberman and Lieberman 1994, Lieberman et al. 1996) in the log-and-leave. Statistical comparisons of forest structural characteristics at La Tirimbina in 1998 are presented below.

Stand turnover rates are community properties subject to change under management in the same way as stand structure and composition, one of the least-understood components of stand turnover in tropical forests being mortality. We calculated the exponential mortality coefficient l and the corresponding stand half-lives (Sheil et al. 1995) for 1993–1998 at La Tirimbina, under the assumption that the probability of death is constant over time. Calculations were for underlying 'natural' mortality among trees $\geq$ 10 cm d.b.h., obtained by excluding trees killed by management operations from the calculations. Excluded trees included those damaged but not immediately killed by harvesting, for which the mortality rate was higher than for undamaged trees (unpublished data). Although characterisation of mortality directly caused by management operations is vitally important, natural mortality is appropriate as a measure of fundamental change in forest functional characteristics. However, Table 1 also includes mortality parameters for the stand including trees damaged by the timber harvest, as these may be more directly comparable with data from other studies of logged or managed forests. Finally, note that in relation to silvicultural regime and tree attributes, patterns of mortality among commercial trees (unpublished data) were similar to those for whole stands reported here.

Table 1. Mean values (standard deviations in parentheses) of stand-level mortality parameters, 1993–1998, in *Pentaclethra* forest at La Tirimbina. See text for details of calculations. Abbreviations for silvicultural regimes: L/L = log-and-leave; Lib./ref. = liberation/refinement.

Silvicultural regime and population considered	N_{93}	l (%)	Half-life (yr)
L/L: natural	502.3 (98.3)	2.02 (0.68)	37.0 (12.0)
All	503.7 (97.2)	2.08 (0.63)	35.5 (10.4)
Lib./ref.: natural	374.0 (47.5)	3.10 (0.72)	23.2 (5.8)
All	375.7 (47.6)	3.19 (0.72)	22.5 (5.4)

Whole-stand natural mortality rates recorded by Lieberman et al. (1985) at La Selva were 1.8–2.2% and that at Corinto was 2.0%. The mean value of l in the log-and leave plots at Tirimbina was within this range, even though it rose as expected when damaged trees were included in the calculations (Table 1). Treatment effects on mortality rates were statistically significant ($p<0.05$) in the La Tirimbina experiment, however, l being markedly higher in the liberation/refinement plots than in the log-and-leave plots (Table 1).

What factors are linked to mortality at La Tirimbina, and how might possible differences between silvicultural regimes be explained? As discussed by Johns (1997) and Finegan and Camacho (1999), mortality is likely to be higher after canopy opening in logged and/or silviculturally treated stands. Damage caused by the breaking up of poison-girdled trees may contribute to mortality in silviculturally treated stands and was not scored at La Tirimbina, although it has been shown that this is much less damaging than the uprooting, breakage or felling of living trees. To further explore possible causes of mortality, we used *G*-tests to examine the null hypothesis of independence of mortality and tree attributes for whole stands,

using data for 1990–1998 and analysing the two silvicultural regimes separately. Trees killed or damaged by management operations were excluded. The proportions of trees dying were not statistically independent ($p<0.05$) of diameter increment (mortality was particularly marked among trees with zero or negative diameter increments), crown form (mortality was greater among trees with poorly formed crowns), or diameter class, which showed a complex relationship to mortality. Most studies have found mortality ≥10 cm d.b.h. to be independent of d.b.h. class in tropical forests (e.g. Lieberman et al. 1985), although in managed forests it may increase among large trees, for example, due to susceptibility to disease and exposure to wind. Whole-stand patterns of mortality in relation to diameter increments and crown form at La Tirimbina could support a hypothesis that mortality has a possibly density-dependent link to low vigour. Further work is required on this point, however. Diameter increments ≥ 10 cm d.b.h. are not independent of species adult size, for example (Finegan et al. 1999). Thus the many understorey and middle-storey tree species of *Pentaclethra* forests are generally slow-growing and their contribution to the non-independence of mortality and increment may be more specifically linked to maturity and senescence than to density-dependent factors. In addition, trees with poorly formed crowns and zero or negative growth represent relatively small proportions of all dead trees, and studies in managed forest at Corinto indicate that density-independent localized disturbance is the single most important cause of mortality (unpublished data). Higher mortality in the liberation/refinement plots at La Tirimbina, even among fast-growing (see below) commercial trees, is also consistent with a hypothesis of predominantly density-independent causes of death.

Growth data are presented from La Tirimbina only for the period 1993–1998, as statistically significant differences between silvicultural regimes were evident from 1993 onwards (Finegan and Camacho 1999). There were no treatment effects on either absolute or relative basal area increments at the site, for whole stands or commercial trees (Table 2). Absolute commercial basal area increment was higher than that for the whole stand under the liberation/refinement treatment (Table 2) due to the deaths after 1993 of several large, non-commercial trees poison-girdled in 1991. The use of periodic annual means of the median diameter increment as single response variables per individual plot (Finegan and Camacho 1999) yielded a statistically significant treatment effect for commercial trees ($p < 0.05$) and a marginally significant effect ($p = 0.06$) for potential crop trees, growth being faster in liberation/refinement plots in both cases (see also Figure 1). Increased mortality under silvicultural treatment, already discussed, is the reason why diameter increments showed a significant treatment effect while net basal area increments did not.

Growth of potential crop trees is the most suitable response variable for the assessment of the effect of the silvicultural treatment, as these trees were sought out in the field for liberation. In addition, it is possible that part of the difference of median diameter growth rates between silvicultural regimes for all commercial trees is an artefact of the elimination by the treatment of some slower-growing trees (e.g. commercial trees with poorly-formed crowns). The possibility of such artefacts is eliminated by the comparison of potential crop trees with their uniform crown and stem form characteristics.

Analysis of the plant diversity data is limited to the year 1998 in the present paper, eight years after the timber harvest, and seven years after the silvicultural treatment. Of the structural and floristic parameters analysed for the La Tirimbina experiment, only basal area ≥10 cm d.b.h. showed a statistically significant treatment effect, the mean value in the log-and-leave plots, at 24.5 m^2 ha^{-1}, being some 25% greater than that of the liberation/refinement plots (Table 3). Diversity parameters did not differ between the two silvicultural regimes at La Tirimbina, in either size class (Table 3), and their values were similar to those of comparable old-growth forests (A.H. Gentry, personal communication; data from old growth at La Selva (Lieberman et al. 1985, 1996) and Corinto show the range of species richness to

Table 2. Mean values (1993–1998, standard deviations in parentheses) of net basal area increment (totals for the period, in m^2 ha^{-1}) and the median diameter increment (mm yr^{-1}), under the two silvicultural regimes at La Tirimbina. Abbreviations as in Table 1.

Response variable	Silvicultural regime L/L	Lib./Ref.	P*
Whole stand			
Absolute basal area	2.28 (0.8)	1.33 (1.1)	0.34
Relative basal area	0.10 (0.03)	0.07 (0.06)	0.51
Median dbh	1.8 (0.15)	3.5 (0.93)	0.086
Commercial trees			
Absolute basal area	1.53 (0.21)	1.49 (0.65)	0.89
Relative basal area	0.13 (0.01)	0.13 (0.06)	0.82
Median dbh	4.2 (0.58)	7.3 (1.68)	0.037
Potential crop trees			
Median dbh	4.4 (0.44)	8.4 (2.2)	0.06

*F-test, treatment effect

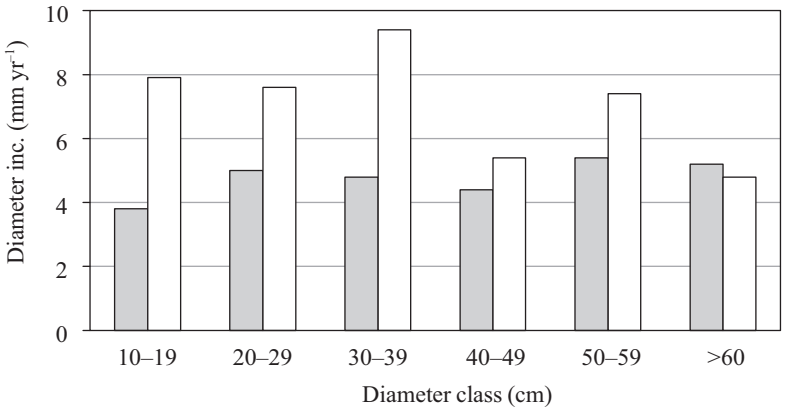

Figure 1. Periodic annual means of the median diameter increments of potential crop trees under the two silvicultural regimes at La Tirimbina, 1993–1998. Filled bars, log-and-leave plots, open bars, liberation/refinement plots.

be 83–115 ha^{-1}, and of *H*' to be 3.77–4.1, ≥ 10 cm d.b.h.). Thus forest diversity has not been reduced by disturbance at La Tirimbina, even though some species represented by one or a small number of individuals ≥ 10 cm d.b.h. in the plots there were initially lost due to logging damage or silvicultural treatment (the 'random mortality' of Webb and Peralta (1998); see also Johns 1997, Chapter 4).

While the diversity of the managed forest at La Tirimbina was similar to that of undisturbed forests, pioneer tree species were more abundant in the stand ≥ 10 cm d.b.h. at La Tirimbina than in the undisturbed plots at Corinto, from which short-lived pioneers were absent.

Table 3. Comparisons of parameters of stand structure and diversity under the two silvicultural regimes at La Tirimbina for 1998. Sample areas were 1.0 ha for the overstorey (≥ 10 cm d.b.h.) and 0.2 ha for the understorey (≥2.5 cm and < 10 cm d.b.h.). Abbreviations for silvicultural regimes as in Table 1.

	Overstorey		Understorey	
Parameter	L/L	Lib./Ref.	L/L	Lib./Ref.
Trees ha^{-1}	535.7 (95.80)	453.4 (76.80)	411.7 (69.3)	441.0 (54.6)
Basal Area (m^2 ha^{-1})	24.5 (1.41)	19.9 (1.87)*	0.82 (0.10)	0.82 (0.11)
Species richness	111 (7.2)	106 (2.0)	150.7 (5.5)	147.0 (11.1)
H'	3.91 (0.211)	3.97 (0.057)	4.6 (0.23)	4.5 (0.07)
Evenness	0.83 (0.036)	0.85 (0.015)	0.91 (0.04)	0.91 (0.01)
Fisher's a	43.5 (8.28)	44.0 (3.00)	88.4 (16.42)	76.8 (4.99)

*$p < 0.05$ (*F*-test, treatment effect)

Conversely, lianas were less abundant and diverse in both size-classes at La Tirimbina than in old-growth (unpublished data). Pioneer and liana abundance within La Tirimbina did not differ between treatments, however (unpublished data). Nor did compositional similarity between plots at La Tirimbina show evidence of a pattern related to silvicultural regime, mean values of Czekanowski's similarity coefficient between plots within treatments differing little from those between plots in different treatments, in both size-classes (for the overstorey, for example, values were 0.58 (s.d. 0.093) within log-and-leave plots, 0.59 (s.d. 0.061) between log-and-leave plots and liberation/refinement plots, and 0.58 (s.d. 0.05) within the latter plots). The most marked compositional change at La Tirimbina was the expected and probably long-lasting one (Guariguata and Dupuy 1997) between the vegetation of logging roads and the rest of the forest, it being notable that silvicultural treatment differs from harvesting impacts in not producing an influx of short-lived pioneer species. More subtle compositional change is clearly evident, however, in the reductions of population sizes of relatively common non-commercial species by the liberation/refinement treatment. For example, trees of *Dystovomita paniculata* (Clusiaceae), a very slow-growing (Finegan et al. 1999) middle-storey tree, were eliminated during the liberation stage of the treatment, their abundance declining markedly between 1990 and 1998 (Figure 2). The combination of 'targeting' by silvicultural treatment and slow growth probably renders populations of species such as *D. paniculata* particularly sensitive to decline under silvicultural regimes such as that of the liberation/refinement plots at Tirimbina. Commercial species are the other obvious candidates for population decline under management, of course; with the exception of *Pentaclethra macroloba*, however, none of those at La Tirimbina are sufficiently abundant for meaningful analysis of population trends using the PSP data (see following section).

Timber Production, Plant Diversity and Sustainability Evaluations using C&I

Our short-term case study gives a preliminary indication that controlled selective logging, at intensities typical for the region, can be consistent with the maintenance of forest productive capacity and conservation of both plant diversity and most elements of forest composition in Central American *Pentaclethra* forests. The same preliminary indication was obtained by Webb and Peralta (1998) for swamp forest of the region. Diameter increments of commercial trees are raised by silvicultural treatment and such intervention could also be consistent with

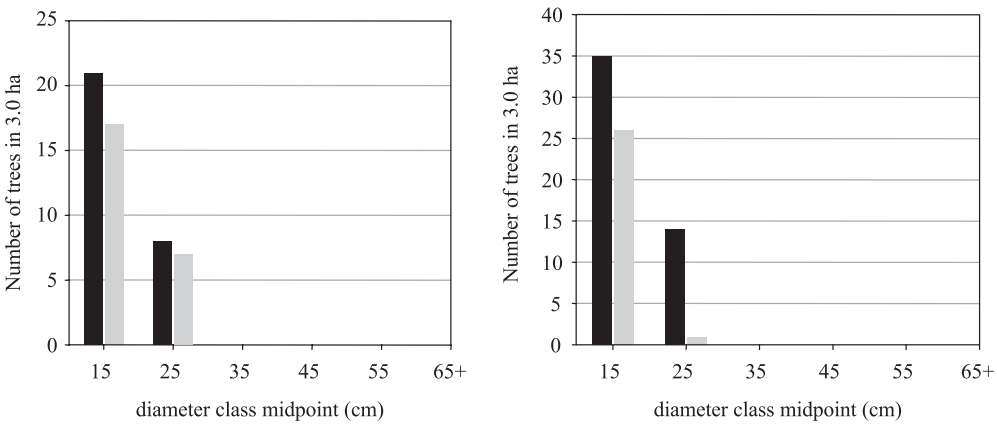

Figure 2. Diameter distributions in 1990 (black bars) and 1998 (shaded bars) for the non-commercial middle-storey tree species *Dystovomita paniculata* at La Tirimbina, under the following silvicultural regimes: (a) log-and-leave; and (b), liberation/refinement.

the maintenance of plant diversity, though its effects on composition of non-commercial species are greater than for logging only. In addition, uncertainty remains regarding the benefits of silviculture to forest production because of the initially higher mortality rates in treated plots – while treatment can presumably reduce density-dependent mortality, the implications of the apparent importance of density-independent death in managed *Pentaclethra* forests require further study. But what points are raised by these results regarding the evaluation of plant diversity conservation in the C&I context?

Best practice and precaution remain basic elements of tropical forest management, and can be assessed through input and process indicators. The designation of unlogged reserves in fmus, these covering the range of forest types present, is undoubtedly an important precautionary measure. In turn, it is obvious that direct management impacts on components of plant diversity can be minimized by best practice. Thus the planning and construction of road networks using RIL guidelines, minimizing logging damage and the area of road vegetation in the regenerating forest, is a useful though very specific indicator for plant diversity conservation. The case study indicates that silvicultural treatment should be expected to have a drastic impact on the viability of populations of some non-commercial tree species, and the application of measures to mitigate this impact, such as the conservation of a proportion of the adult trees which would be eliminated, may be a useful indicator. Additionally, general principles suggest the concept and assessment of sustainability should also be linked to types of silvicultural treatment. Liberation thinning only eliminates trees which are judged to be competing directly with potential crop trees – as opposed to the indiscriminate culling produced by refinement – and its use could be specified as an impact reduction measure. The case study also indicates that lianas – important contributors to tropical rain forest diversity and function – are strongly impacted by management operations. At the input and process level, indicators could focus on whether pre-harvest liana cutting is done only where these plants are expected to cause problems during tree felling (which it usually is in Central America – B. Louman, personal communication), and not indiscriminately. Economically valuable lianas, such as the common and easily recognizable medicinal *uña de gato* (*Uncaria* sp., Rubiaceae) in rain forest of northeastern Nicaragua (B.

Finegan, personal observations) should be identified and measures to protect them implemented (B. Louman, personal communication). Vines and lianas do not currently present a problem to regeneration and growth of timber in Central America, although this may not always be the case.

There now remains the general principle that evaluation and monitoring of outcomes is necessary: what are the effects of the plant diversity conservation measures being taken, and what unexpected forest responses to intervention arise? The fact that the data available for *Pentaclethra* forests are short-term and an outcome of silvicultural treatment at La Tirimbina that should be considered unexpected – increased mortality rates – has already arisen, backs up this general principle at a level specific to the forest type or the site. So what should be monitored? The human and logistical requirements for species identification in tropical forests have led to many proposals for diversity monitoring using indirect or surrogate indicators, such as relatively easily-measured forest structural parameters (e.g. CIFOR C&I Team 1999). The La Tirimbina case study shows, however, that forest structure may change – in terms of basal area (this paper) and size-class distributions (Finegan and Camacho 1999), while stand diversity does not. It seems likely that stand density (trees ha^{-1}) is more closely related to stand diversity, and that recruitment has, therefore, been a key factor in the maintenance of diversity post-disturbance at La Tirimbina. However, overall change in forest structure is clearly not predictive of change in diversity of plants, although it may be for animals and birds. Structural indicators cannot, therefore, be unreservedly recommended as surrogates for plant diversity in managed *Pentaclethra* forests, at least within the range of disturbance intensity found at La Tirimbina, which is typical for the region. Therefore, more direct methods would have to be used, or other surrogates validated. Monitoring of changes in community-level floristic parameters, as well as in the sizes and structures of populations of the more abundant tree species, could be based on permanent sample plot techniques adapted for the purpose, as in the present paper. As species diversity and species composition may vary independently, however, monitoring should not only ask *how many species are being conserved*?, but also, *which ones*? Regarding this second question, high species diversity makes a focal species approach (e.g. Noss 1999) worth considering and testing. Focal species categories (which are predicted to be susceptible to population declines under management – some of which are identified in the previous paragraph on the basis of the case study) and/or species which belong to a threat category requiring conservation action, could be emphasized. As most tree and liana species are not sufficiently abundant to be monitored individually in PSPs, and those that are sufficiently abundant may for that same reason be least susceptible to population declines, monitoring of focal species would have to employ population censuses over large areas. Human and logistical requirements mean that responsibility for such monitoring should not usually rest with the forest manager. Discussion of the policy and institutional mechanisms through which monitoring might be achieved is beyond the scope of the present paper, but the participation of research institutions is clearly required (cf. Noss 1999). We offer two suggestions regarding priority-setting for monitoring in Central American forests. Firstly, if further work confirms that plant community diversity is robust, as suggested by the La Tirimbina case study and that of Webb and Peralta (1998), monitoring at this level should not be considered high priority and focal species should be emphasized. Secondly, biological monitoring in production forests should focus on forest types of limited extent, unusual characteristics and/or a high degree of threat (Finegan et al in press), on high-intensity logging scenarios, and where relatively drastic interventions with poorly documented consequences for biodiversity are employed, such as silvicultural treatment or intensive fellings in even-aged stands. More generally, however, realistic conservation objectives for production forests must be defined or negotiated – not all components of biodiversity can be preserved everywhere.

Capacity for progress towards adaptive management in the neotropics is currently limited, while with respect to plant diversity, longer-term research data and modelling of forest responses are required to strengthen the basis for understanding and effective monitoring of the outcomes of management. Therefore, the adoption of adaptive management should be considered a medium-term goal. Validated monitoring techniques for aspects of ecological sustainability other than the silvicultural condition of the next crop or forest growth and yield, accompanied by a policy and institutional framework which fosters the development and implementation of relevant and practical monitoring programmes, should be central components of a phase in the evolution of SFM which builds on precaution and best practice to move towards adaptive management and, perhaps, greater freedom for the manager to manipulate the forest.

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A Framework for Monitoring Indicators of Ecological Sustainability in Tropical Forestry[1]

Jaboury Ghazoul

Imperial College of Science, Technology and Medicine
Silwood Park, Ascot, Berkshire, UK

Abstract

Certifying ecologically acceptable forest management requires monitoring forest conditions and the environmental impacts of management activities. Through adaptive management, assessments that reveal excessive environmental impacts require revision of the management plan so that the ecological functions and attributes of forest ecosystems are maintained within acceptable limits. But how are these acceptable limits determined? And how can 'normal' or 'natural' conditions be defined when these are temporally or spatially variable. To determine the desired biological state of a forest indicator baseline values, together with some measure of variability under natural conditions, are needed. A useful Ecological Criteria and Indicator set should, therefore, provide objective standards for evaluation, and these standards should account for spatial and temporal variation in indicator states as well as resilience to anthropogenic disturbance. A framework is presented, within which the standards for assessing ecologically sustainable forest management might be defined. The published literature is drawn upon to determine the responses of selected indicators to natural and anthropogenic disturbances. Using these values we can begin to predict expected ecological conditions of a sustainably managed forest given information on forest type, disturbance intensity and time since disturbance.

Keywords: biodiversity, Criteria and Indicators, forest ecology, forest management

1. Introduction – Forest Certification and Evaluation of Biodiversity

Forest certification aims to promote sustainable forest practice through independent evaluation of forest management against a number of objective and unambiguous

1 This paper is based substantially, with permission, on Ghazoul and Hellier (2000). Setting critical limits to ecological indicators of sustainable tropical forestry. International Forestry Review 2(4):243–253.

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requirements (Principles and Criteria). In the evaluation process the requirements translate into a number of Indicators and Verifiers to ascertain whether management planning and implementation of the plans meets the requirements set out. An 'Indicator' is any variable or component of the forest ecosystem or relevant management system that is used to infer attributes of the sustainability of utilisation of the resource. 'Verifiers' are the data or information that need to be collected for the assessment of any particular indicator. The aim of an ecological Criteria and Indicator set (C&I) is to provide an objective and unambiguous set of Indicators and Verifiers against which environmentally sustainable forest management may be evaluated.

But how should we determine what is an acceptable desired state in terms of environmental sustainability? On the premise that pre-disturbance ecological attributes are desirable states and that ecological sustainability aims to minimise departure from such states, then two further questions are demanded: (1) what are the original (or desired) conditions of the verifiers to be used in any assessment process; and (2) what is the operational time-scale for assessment?

The second of these questions is easier to deal with, as the relevant time-scale can be set according to the local context. Almost any forest management system may be considered sustainable given sufficient time for recovery. Therefore, the time-scale within which management practices may be said to be sustainable must be specified, and subsequent assessment must refer to this time-scale. 'Sustainability' is used in this context to refer to a representative tropical forest cutting cycle of, say, 40 years, by which time data generated by ecological verifiers should be statistically identical to equivalent data from undisturbed forest. Thus the goal of a forest manager would be to secure the desired value for each verifier in the C&I set by the end of the logging cycle at the latest (i.e. 40 years after the initial harvest). Ultimately, it makes little difference as to the time-scale selected provided that it allows for a return to the pre-determined goals of sustainability, it is clearly defined within the objectives and it is convincingly justified.

While recognising that a return to the exact original state is impossible, ecological sustainability infers the conservation of certain key functions and parameters of the ecological system. The CIFOR C&I set have been designed with this in mind. Therefore, it is necessary to place values on the original state of the selected verifiers (Question 1 above). The 'baseline' values need to include a measure of the average condition of the verifiers, and an associated measure of variability, such as standard deviation, to account for natural spatial and temporal heterogeneity over a representative period of time (e.g. the length of a single cutting cycle). The goal for recovery can then be defined as the set of verifier values that lie within one standard deviation of the mean value. If less rigour is needed, the acceptable range of verifier states may encompass values that lie within two (or other multiple) standard deviations of the mean. Thus recovery may be more formally defined as the point at which the state of the verifier in logged forest is statistically identical to the state of the verifier in unlogged forest. The variability of values (i.e. its standard deviation) of a particular verifier in natural undisturbed forests will determine its utility for assessing anthropogenic impacts. Clearly, verifiers that generate a set of highly variable results under similar conditions are of little value for the rapid assessment of disturbance impacts, and probably of little value at all.

Finally, information on the rate and directionality of indicator responses to disturbance as measured by verifiers is needed, to which data generated from the implementation of C&I can be compared for an assessment of sustainability. Information on the patterns of response can be useful in determining whether particular verifiers should be rejected from the C&I set. A clear and ubiquitous pattern of recovery enhances the value of a verifier as a monitoring tool, while the absence of any clear pattern indicates that the verifier concerned is unlikely to be useful in evaluating sustainability of forest practice.

2. Conceptual Framework

2.1 Critical time-thresholds

Different verifiers have different patterns of recovery. Such variation can form the basis for a series of checks, using different verifiers, conducted at intervals through the regeneration phase of the cutting cycle. To satisfy the condition of sustainability all verifiers, except for the special case of landscape pattern verifiers, are expected to have achieved an acceptable state by the end of the 40-year harvesting and growth cycle. Thus a *critical time-threshold* might be defined for each verifier as the expected time after disturbance at which the verifier value is statistically indistinguishable from the undisturbed (baseline) value (or the prescribed desired condition, if different from the undisturbed state). If verifier recovery rates are known it will be possible to predict the critical time-thresholds. Rapidly recovering verifiers provide early indications of unsustainable practice (if the expected targets are not met), while long-term verifiers confirm the sustainability of practice at the end of the regeneration cycle. In this way unsustainable practices may be identified and modified as information is generated by verifiers at intervals throughout the logging cycle. This opportunity for adaptive management provided by the CIFOR C&I set is a primary advantage over other C&I systems.

The actual critical time threshold set may, ultimately, be a subjective decision informed by available information (such as that contained in this review or generated by the implementation of C&I in the FMU). Critical thresholds might even be reached by expert and stakeholder consensus. In any case, having set and justified critical time thresholds, a transparent assessment system for adaptive management can be constructed, which can be checked by third party certifiers. Ultimately, verifiers can be placed into a framework according to whether the information they provide is useful for assessing sustainability early or late in the regeneration cycle (Table 1).

Table 1. A framework of critical time-thresholds for categorising expected verifier recovery times.

Critical time-threshold	Years since logging
very early	<5
early	5–10
early-mid	10–20
mid-late	20–30
late	30–40

2.2 Monitoring systems

Regional datasets could be used to define critical time-thresholds for verifiers, while baseline states against which verifiers are to be evaluated should be derived from data collected at the FMU level, albeit informed by regional baseline values. There are two reasons for using FMU datasets to define baseline states: (1) FMU datasets are representative of local conditions; and (2) the collection and analysis of such data by the forest manager is in itself indicative of good management practice (see Figure 1). Comparison with regionally-derived verifier baseline values will allow assessment of the quality of the data collected in the FMU, or highlight substantial differences to those expected in the region. Thus, if the value of any verifier is statistically distinct from expected regional values, a forest manager might be expected to account for the difference. In such cases a forest manager should decide whether

the objective is to return the forest to a condition similar to that described by the regional state, or whether an alternative goal (such as maintenance of a unique and rare forest type or a non-natural condition) is more desirable. A discrepancy may also be due to inadequate implementation of the monitoring procedure, which might itself be an indicator of implementation of good practice guidelines (Figure 1).

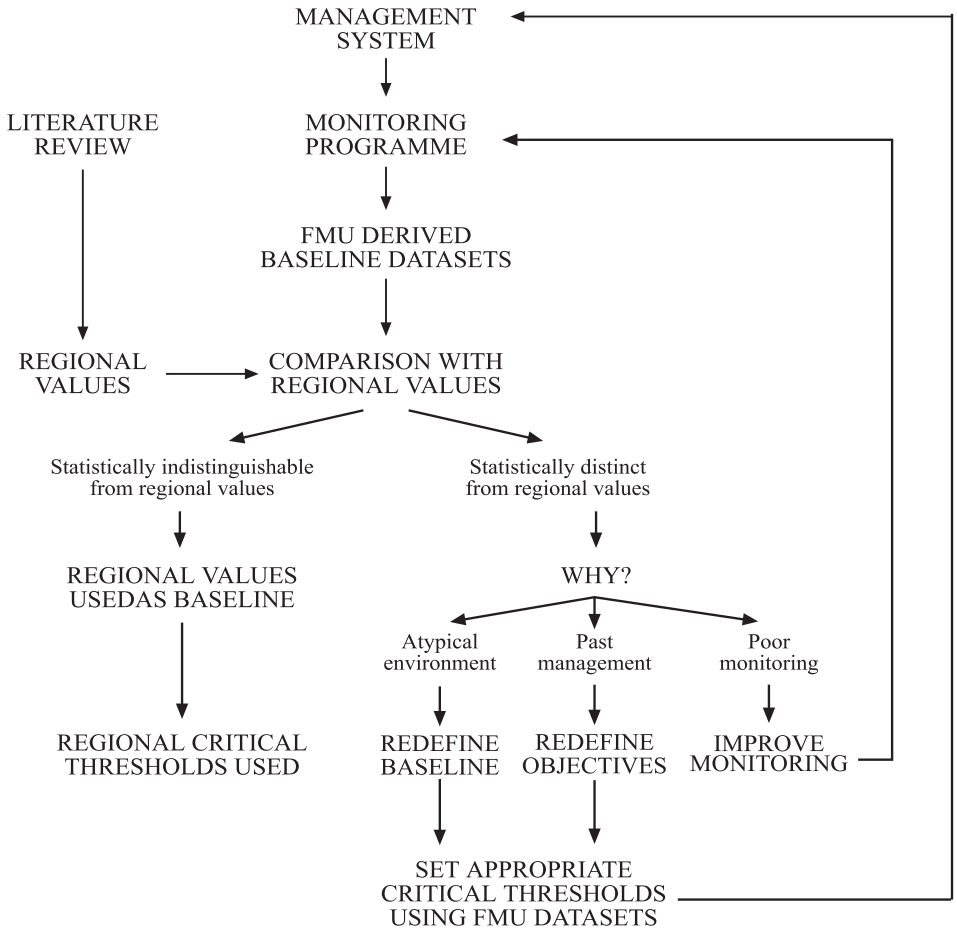

Figure 1. Setting baseline values for particular FMUs.

In addition to collection of baseline data as part of the C&I programme, forest managers would also expect to collect data on the state of selected verifiers at certain times during the cutting cycle. Each assessment stage is, effectively, a check on actual recovery to be compared to the expected recovery under a sustainable scenario. These checks will assess verifier recovery and provide information for adapting and improving future management, should expected verifier states not be met. Hence, the forest manager might demonstrate good management for ecological sustainability either by the performance of the verifiers or by reacting to the information produced.

From a sustainable management perspective both these aspects of management could be considered. For example, failure of a verifier to meet an early critical time-threshold could be

offset by a demonstration that the forest manager has modified existing operational practice accordingly. Results from subsequent tests showing poor recovery of late critical time-threshold verifiers would be acceptable only if management practice had indeed been modified in response to results form early time-threshold verifiers (Figure 2). Alternatively, later checks may show adequate recovery of all verifiers, in which case modification of operations may not be needed. Such a system provides a forest manager with clear and measurable targets that allow for modification of forest operations to meet environmental requirements and do not necessarily imply poor management if expected verifier values are not initially met.

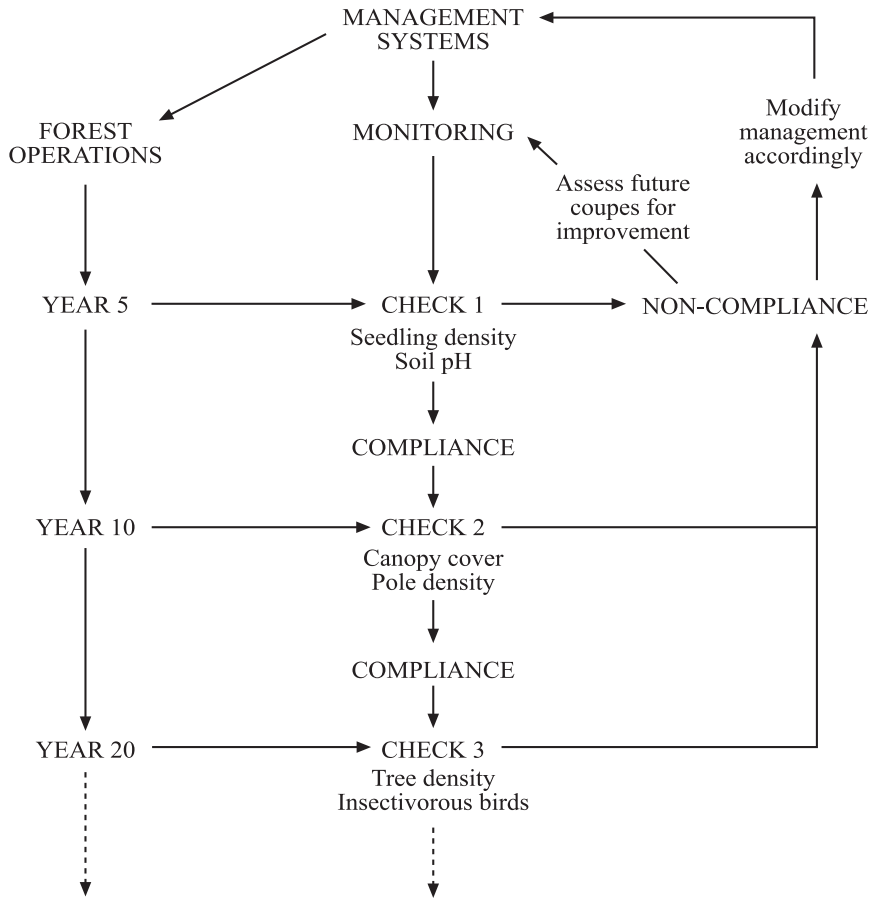

Figure 2. Monitoring system defined by critical time-thresholds.

3. Objectives

To implement a complete C&I system at the FMU scale two values are needed for each verifier.

1. *Baseline (or target)* – the average value of the verifier in the desired state (which may or may not be its state prior to management intervention) that will be the target to which a

forest manager will aim to reach. Associated with the baseline value should be a measure of variability to reflect temporal and spatial variation.

2. *Pattern of recovery* – the expected rate and direction of change in verifier values through a time series following forestry operations to the desired target state.

In this paper I aim to present a first attempt, by drawing upon the relevant published literature, at defining the standards for assessing ecological sustainability of management practices using the CIFOR ecological C&I set (Boyle et al. 1998). Thus, I aim to quantify patterns of forest recovery, as measured by selected verifiers, following disturbance by logging in FMUs. Two types of information are sought: (1) the amount of natural variation observed for each verifier in undisturbed forest; and (2) recovery patterns of verifiers after human disturbance.

4. Forest Structure

Verifiers: basal area
canopy openness

4.1 Variation among regions and ecosystems

The classification of forest formations is based in part on vegetation structure and plant physiognomy. Due to analogous biomes developing in the three major tropical regions of the world (Whitmore 1990) several global tropical forest formations are recognised, including mangroves, humid forests, dry forests and savannas (Hartshorn 2001). These similarities in tropical forest structure arise, to a large extent, from climate and soil. The climatic similarity of tropical moist forests (with rainfall generally exceeding 1500–2000mm/yr and not less than 100mm for any month) has been noted by many observers (e.g. Leigh 1975), and the density and basal area of tropical moist forests are generally uniform (Wadsworth 1997) with limited regional variation (Table 2). Thus values for forest structure verifiers may have regional or even global applicability, provided attention is paid to forest type. Therefore, data on forest structure verifiers from similar forest formations around the globe can be compared and, if shown not to be greatly variable in natural undisturbed conditions, can be used to derive generic baseline values. Once generic applicability is established an investigation of the recovery patterns of verifiers can be undertaken to determine the generality of these patterns. Here two examples, the basal area and canopy cover verifiers, are used to illustrate these points.

4.2 Canopy cover and basal area under undisturbed forest conditions

Canopy cover in unlogged tropical forests is generally high. Most studies record canopy cover as more than 90% and all studies recorded canopy cover exceeding >80% (Table 3). The exact definition of ‘canopy cover’ will affect the results obtained, but this is often not given by authors. On the basis of seven studies from tropical wet forests around the globe, a baseline value for canopy cover in this forest type is 91±5%. There are undoubtedly more studies that can be included to obtain greater confidence in this baseline value, but this is a first step in identifying baseline and, therefore, target values, for the canopy cover verifier.

The variability among forest types is likely to be very much greater than within forest types and baseline values will need to be calculated for each forest type. More problematic is the

Table 2. Regional variation in density (trees > 10cm DBH) and basal area.

Location	Forest type *	Density trees/ha	Basal area m^3/ha	Reference
Asia				
Seplilok, Sabah	LD	660	42	Nicholson 1965
Pasoh, Malaysia	LD	530	25	Manokaran and La Frankie 1990
Menyala	LD	492	32.5	Manokaran and Kochumen 1987
Danum, Malaysia	LD	470	27	Newbery et al. 1992
Berau, Indonesia	LD	530 ± 71	31.5 ± 4.2	Sist et al. 1998
Lagong	HD	559	41.7	Wyatt-Smith 1949
Mulu, Sarawak	LR	686	41	Proctor et al. 1983
Uppangala, India	LME	625 ± 28.5	39.7 ± 34.7	Pascal and Pelissier 1996
Latin America				
El Verde, Puerto Rico	LMR	593	36	Crow 1980
La Selva, Costa Rica	W	446	29	Lieberman and Lieberman 1987
Amazon, Brazil	Ur	625		Rankin de Merona et al. 1990
Elie, French Guiana	H	609	35	Pelisser and Riera 1993
Africa				
Makokou, Gabon		450	35	Hadlik 1982
Omo, Nigeria	MSE	562	30	Okali and Ola-Adams 1987
Kade, Ghana	MSD	552	31	Swaine et al. 1987

* Forest type defined after Pascal and Pelissier (1996): LR, lowland rain; LD. lowland dipterocarp; HD, hill dipterocarp; LME, monsoon evergreen; LMR, lower montane rain; W, wet; UR, upland rain; H, humid; MSE, moist semi-evergreen; MSD, moist semi-deciduous).

Table 3. Canopy cover of forests from different regions.

Location	Canopy cover	Reference
Gabon	93	White 1994
Amazon	92	Johns 1996
Costa Rica	91.4 ± 4.5	Webb 1997
Guiana	87–92	Thiollay
Amazon	80	Uhl and Viera 1989
Panama	95	Lang and Knight 1983
Venezuela	94.1 ± 1.5	Mason 1996

variability within sites due to topographical or micro-site differences in soil type. Differences in soils and topography can result in major variation in forest structure even within a single forest type. This clearly has implications for definition of verifier critical values and planning of monitoring protocols, and in such cases greater emphasis may need to be placed on determining microsite-specific verifier values at the local scale.

A review of basal area estimates from five studies in lowland moist tropical forest gives a mean basal area value of 35±3.4m^3/ha (Table 4). Table 4 also illustrates how variability of the measured verifier can be very different between sites, and this can be a function of the sampling protocol used. Sampling protocols relevant to particular forest types and regions have yet to be developed, but when they are attention to statistical power will be imperative to the design of satisfactory sampling regimes. As with canopy cover, the inclusion of additional studies in the calculation of this value will increase confidence in the baseline value and clarify its generality.

Table 4. Coefficients of Variation for basal area.

Forest type	Basal area m^2/ha	CV	Sample size	Reference
Low moist	31.5 ± 4.2	13	48 x 1 ha	Sist et al. 1998
Low moist	27.2 ± 2.86	10	8 x 0.16 ha	Pinard and Putz 1996
Low moist	33.2 ± 10.7	32	25 x 0.04 ha	Kammesheidt 1998
Low moist	33.2 ± 2.1	6	not given	Kammesheidt 1998
Monsoon	39.7 ± 34.7	87	5 x 0.6 ha	Pascal and Pelissier 1996
Mixed deciduous	13–63	31	33 x 0.2 ha	Rundel and Boonpragob 1995
Dry dipterocarp	7–42	27	52 x 0.2 ha	Rundel and Boonpragob 1995

4.3 Patterns of canopy cover and basal area recovery

4.3.1 Initial impact

Damage to the stand and canopy loss is generally related to the number of stems harvested per hectare (Webb 1997), but can also be strongly influenced by the nature of the logging operations. The volume of timber extracted varies across regions according to the stocking of commercially valuable stems and regional market demands. In general volumes harvested from Asian dipterocarp forests tend to be around 4–8 trees/ha or equivalent to 20–30m^3/ha, but may be as high as 100m^3/ha in forests where a high proportion of stems are commercially valuable (Whitmore 1990). Extraction and damage in Latin America tend to be less than in SE Asia, but this varies among different countries and forest types. Logging intensity in Africa is generally the lowest of the three tropical regions due to high costs, low local demand and a limited number of species used for the export market (White 1994). The very great variability in logging intensity makes it difficult to establish generic recovery patterns of forests. Clearly, logging at the highest intensities are likely to be unsustainable under the definition of sustainability used in this paper (i.e. return to conditions that are statistically indistinguishable to the pre-disturbance conditions within a 40-year time frame). For the purposes of objective assessment some quantification of what is deemed sustainable is needed.

In addition to the volume extracted a forest manager should also consider the damage caused to the forest by the extraction process. Damage to surrounding trees by logging is often considerable, ranging from approximately 20 to 70% of stem mortality (Kurpick et al.

1997). In Asia, where extraction levels are generally high, the damage to the remaining stand is correspondingly high and is about 50% for conventional logging operations (Kurpick et al. 1997). Reduced impact logging (RIL) techniques (directional felling, planned skid trails, etc.) can reduce damage to the remaining stand by 50% (Sist et al. 1998). However, the relationship between volume harvested and damage may not always be linear. Sist et al. (1998) recorded a large increase in damage when >8 stems/ha were cut in RIL systems.

Studies from Latin America report reductions in canopy cover of 10–40%. In Africa canopy cover reduction by logging is relatively low (<10%), while in Asian dipterocarp forest it is high corresponding to the high levels of extraction.

4.3.2 Recovery

Crown extension by the remaining trees means that canopy cover can return to pre-disturbance levels relatively quickly, if logging is light. Gaps may also be closed by advanced regeneration or fast growing pioneers. Mason (1996), for example, found canopy cover in a Venezuelan forest to be 90.9±7.3% in plots logged 6 years previously (3–7 stems/ha), compared to 71.9±25.5% in plots logged 1 year before, and 94.1±1.5% in unlogged forest, demonstrating recovery within a few years. Chapman and Chapman (1997) found no differences in forest floor light levels (a surrogate measure for canopy openness) between forest logged at 5–7 stems/ha 25 years previously and unlogged forest in Uganda, indicating apparently full recovery of canopy cover by this point.

The recovery of basal area after logging occurs by growth of remaining trees and new recruitment. Increased light levels following canopy opening in logged sites can promote both these processes, but there is evidence that increased growth rates are short lived. Silva et al. (1995) found that the basal area of logged forest in the Brazilian Amazon increased from 20.3 to 25.9m²/ha in 2 to 13 years after logging (real-time series) compared to an unlogged basal area of approximately 36m²/ha. Diameter increments in recently logged stands were double those of unlogged forest levels, but growth in stands logged 6–12 years previously were similar to that of unlogged forest implying that the stimulus in growth due to increased light levels lasts only a few years. By extrapolating from this rate of basal area increment, it was calculated that a period of 30 years is required for this forest to reach pre-disturbance basal area values. Differences in stand structure due to variable logging intensities were still obvious 25 years later at Kibale, Uganda (Chapman and Chapman 1997): basal area of moderately logged stands (5–7.4 stems/ha) was 35–38% of unlogged forest basal area while lightly logged forest (1–3 stems/ha) was 68% of unlogged levels, implying high initial damage and slow recovery.

As might be expected**,** the time for basal area recovery depends greatly on initial damage. No significant difference in either basal area or stem density between logged and unlogged forest was recorded six years after low-impact logging using elephants in the Western Ghats (Pelissier et al. 1998): logging intensity of 8.5 trees; logged forest, 578 stems/ha and 34.8m^3/ha basal area; unlogged forest, 606 stems/ha and 39.4m^3/ha basal area. If these data are similarly extrapolated, full recovery would take 18 years. The damage associated with logging in this case was very low and may represent the minimum critical time-threshold for basal area. However, there is evidence that the forest was still in a process of recovery despite the absence of significant differences among these verifiers, as differences in basal area and stem density between unlogged and logged forests narrowed further 12 years after logging. At six years, stem density was closer to the unlogged state (4.8% difference) than basal area (12.9% difference), implying that stem density recovers faster than basal area. In contrast, basal area in forest logged (10 stems/ha) in Kalimantan using mechanised extraction, was

only 50% of unlogged forest basal area values, eight years after logging (Cannon et al. 1998). Likewise, Kammesheidt (1998), assessing recovery from logging (10 stems/ha) in Venezuelan lowland moist forest, found that basal area increased from 17.8m^3/ha at a 5-year-old logged site to 22.2m^3/ha at a 19-year-old logged site, which was still only 67% of the basal area of unlogged forest (33.2m^3/ha).

4.4 Key points

Canopy cover can recover relatively quickly (within about 10 years) to values observed in unlogged forest, although recovery can take much longer if the disturbance is excessive. Therefore, canopy cover can be considered an early threshold verifier within the framework of Table 1. Basal area recovers more slowly and can, perhaps optimistically, be termed a medium-late critical time-threshold verifier (20–30 years).

5. Dead Wood and Decomposition

Verifiers: 2.1.6.1 volume of standing and fallen dead wood
2.1.6.2 state of decay of dead wood
2.1.6.3 abundance of small woody debris
2.1.6.4 depth of leaf litter gradient of decomposition

5.1 Dead wood

Dead wood is widely recognised for its importance as a habitat for a variety of invertebrates, and hence as a foraging substrate for vertebrates, in temperate forests (Sturtevant et al. 1997; Ratcliffe 1994). The volume and size structure of dead wood is influenced by stand structure, and this is itself influenced by site and other environmental conditions. Selective logging often produces large amounts of woody debris from residues of felled trees and other toppled stems. Additionally, mortality rates have been shown to increase following logging as trees damaged in the operation or affected by the opening of the stand die. The structure of the stand is altered in selective logging leaving fewer large trees and the generation of large dimension dead wood is, therefore, likely to be lower than pre-logging levels until the stand recovers its size class distribution.

Several chronosequence studies in clear-felled temperate and boreal forests have observed a ‘U shaped’ response (i.e. an immediate increase followed by a reduction and subsequent increase) in dead wood abundance after a disturbance event (Sturtevant et al. 1997) (Figure 3). Following logging there is much woody debris that decomposes slowly, but little additional dead wood input from the regenerating stand. As the stand ages the production of coarse woody debris (CWD) begins to increase, both in terms of volume and mean diameter.

There is much less available information on dead wood in tropical forests although at least one tropical study does show a U-shaped pattern of CWD (Brown and Lugo 1990, Table 5). While selective-felling and clear-felling are very different, the response of dead wood volumes can be expected to follow similar lines (Brown and Lugo 1990): logging residues decay over time and dead wood production of the residual stand takes time to accumulate. The nature of the response after selective logging is likely to differ in that the residual stand will continue to produce dead wood without the time lag observed in clear-felled areas. There

may also be a short-lived initial increase in dead wood volumes after logging due to logging-induced mortality. Therefore, the 'U-shaped' response is still expected, but is likely to be flattened (due to the continual production of dead wood by the residual stand) with perhaps a short-lived peak after logging (logging induced mortality) (Figure 3). The time-scale over which the process takes place is expected to be shorter in the tropics owing to higher decomposition and growth rates. However, this conclusion should be treated with caution bearing in mind the slow increase in basal area following logging reported in some studies.

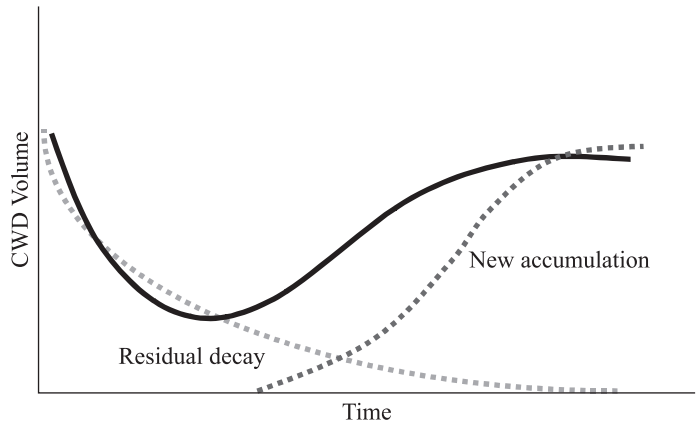

Figure 3. Expected responses of CWD after clearfell logging (dashed line) and selective logging (solid line) in tropical forests.

Table 5. Mass of woody debris in secondary forest of different ages in Venezuela (after Brown and Lugo 1990, data from Saldarriaga et al. 1986).

Forest age	Mass t/ha	% of live wood
10	17.9	35.0
20	1.1	1.6
35	6.1	5.4
60	23.1	16.6
80	16.5	12.1
Mature	22.7	10.1

Data from temperate and boreal forests suggest that the lowest volume of CWD (the time during which logging residues have disappeared but new production of dead wood is low) will occur between about 20 and 50 years respectively after which volume will increase. In the tropics logging-induced mortality of residual stems occur for a few (1–5) years after logging and there is evidence that logging residues will have decayed within about 15 years. The recovery of dead wood volume to pre-logging levels depends on stem density and basal area. The rate of recovery of all dead wood characteristics (volume, size and decay state class distributions) will, therefore, be relatively slow and full recovery under sustainable management is expected by the mid-late stage. The pattern of recovery can be observed at earlier stages through the distribution of dead wood in different decay state classes.

5.2 Decomposition and soil nutrient content

Decomposition rates appear to be little affected by disturbance, except in extreme conditions where the canopy is opened to a degree that results in drying of the litter and soil. Burghouts et al. (1992) found no difference in decomposition across logged and undisturbed forest, while Zou et al. (1995) found that decomposition was slightly higher in secondary forest. If this trend is true then significant differences beyond the earliest stages of regeneration would indicate slow recovery. Therefore, decomposition might be used as an early time-threshold verifier. Soil acidity and organic carbon also recover rapidly following disturbance (Table 6) and these may be classed as very early stage verifiers. Indeed, Enright (1978) found that pH, organic matter and nitrogen content of the soil recovered within two years of heavy logging damage in *Araucaria* forest in Papua New Guinea. Other nutrients took longer to recover. In Australia, Herbohn and Congdon (1998) found no consistent differences in total nutrient accessions in small litter fall (leaves and woody debris <2cm) between forest logged 25 years previously and unlogged rain forest. Acidity is easy to measure, but its link with biodiversity is not as intuitive as other verifiers, and it is important to justify the significance of this and other decomposition verifiers if they are to be adopted enthusiastically. Whether the effort required to monitor decomposition rates and soil nutrients is justified is arguable, although decomposition is clearly an important process in the ecosystem.

Table 6. Soil acidity and organic content under disturbed forest conditions.

	Organic C (%)	pH	Location
Unlogged	3.7 ± 0.87	3.9 ± 0.16	Sabah
17 yr post logging	3.4 ± 1.35	3.6 ± 0.23	
3 yr post logging	3.0 ± 2.00	2.4 ± 1.15	
Undisturbed	6.92	3.78	Cameroon
30 yr secondary	2.96	4.09	
5 yr plantation	2.15	4.38	
Cleared	1.72	5.39	
Undisturbed	6.8	5.49	Western Ghats
Slightly disturbed	5.8	5.67	
Highly disturbed	5.4	5.73	
Pasture + thicket	4.7	5.02	
Open pasture	3.4	5.34	
Plantation	4.3	5.45	
Unlogged	8.2	5.5	Papua New Guinea
1 yr post logging	3.2	4.2	
2 yr post logging	7.6	5.6	

5.3 Key points

- temperate studies suggest clear patterns of CWD response and recovery after logging;
- there are few data on CWD from tropical forests;
- CWD variables make good verifiers for a range of critical time-thresholds up to mid-late stage, but more data are required;
- decomposition, pH and organic carbon show response to high levels of disturbance only. These variables could be early time-threshold verifiers, but whether the effort required to record them is justified is debatable.

6. Discussion and Conclusions

In general there is a shortage of long-term data on ecological responses to logging in tropical regions. Short term studies provide useful information as to the initial effects of logging, but their value in estimating long-term recovery patterns is limited as extrapolations can be highly misleading. The few long-term studies that exist are mostly based on chronosequence measurements where differing extraction rates and methods used for extraction (as well as initial starting condition of the forest) complicate comparisons across sites. As most studies fail to report initial damage or even logging intensity, drawing conclusions about recovery rates from such chronosequence data are difficult.

Defining acceptable forest states must in the context of natural variability over an appropriate time-scale. However, information on the natural variability of verifiers is sparse. Quantifying the natural variation in species diversity and abundance for birds, butterflies and invertebrates in general is complex and has not been attempted within the scope of this review (but see Ghazoul and Hellier 2000). Temporal and spatial variation are often different for different forest types and geographical regions, and their measurement is highly sensitive to sampling effort. Regional and local variability in verifier states suggests that baseline values should be set using data generated within the FMU rather than being based solely on regional averages, though regional averages, derived from reviews such as this, will provide a quality control mechanism for FMU datasets.

6.1 Choice of verifier

The most useful verifiers show a clear, unidirectional response and recovery pattern, i.e. the verifier should show the same direction of response (up or down) after disturbance and a similar pattern of recovery in most or all studies. An ideal suite of verifiers would represent a range of recovery patterns enabling recovery to be assessed at intervals throughout the regeneration cycle. In general forest structure verifiers show clear patterns of response and recovery involving various time-thresholds throughout the regeneration cycle. Data are mostly plentiful for forest structure verifiers and the use of equivalent measurements in most studies facilitates comparisons. Therefore, for these verifiers it is possible to propose critical time-thresholds with reasonable confidence. These verifiers are, furthermore, easy to measure and their monitoring may only require minor alterations of forest inventory practices. Data for forest dynamics verifiers (not discussed in this paper) are also plentiful, but less comparable as the particular variables measured vary across studies and definitions of key components (gaps, pioneer species and different building stages of forest regeneration) are not universally agreed on. However, trends are easy to identify and the precision of critical time-thresholds may be improved by tightening working definitions.

Although there are few data illustrating the recovery patterns of dead wood in tropical forests there is good evidence for relatively predictable recovery patterns. It is possible to draw conclusions about the nature and time-scale to the response of these verifiers (volume, decay, size) from studies in temperate forest, although their extension to tropical environments remains to be tested.

Forest structure and dynamics are common forest management themes. Information on species diversity, in contrast, requires more specific studies that are not normally part of logging operations. In general measures of species richness and abundance do not make good verifiers as species respond differently to disturbance. Species diversity and the similarity between assemblages show clearer, albeit complex, recovery patterns. Among birds, for example, the diversity and abundance of insectivorous and nectarivorous species show clear trends, but butterfly response patterns are more difficult to identify (Ghazoul and Hellier 2000).

6.2 Future research requirements

Long-term recovery data are scarce, and this gap will only be filled by further fieldwork. For example, for tropical and subtropical plantations it has taken more than 30 years to attain accurate data to examine sustainability of yield over three successive rotations (Evans 1999).

A Bayesian statistical approach can be used to integrate expert opinions with the data currently available in the published literature. By creating a logical framework for predicting periods of recovery (i.e. the process for setting critical time-thresholds outlined above) expert opinion can be used to supplement published information. This will be especially important in areas where the literature suggests patterns of long-term response, but where data to support or reject hypotheses are limited.

Field tests of verifiers should be designed bearing in mind current gaps in the literature. Time series studies should include the whole cutting cycle and not just the first few years after logging. This is problematic given that mechanised logging is comparatively recent in some areas, and that it is hard to control subsequent legal or illegal extraction or conversion to non-forest uses. The temptation is to concentrate on the more recently logged stands that are easier to identify and give more accurate results, albeit of limited value.

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Development of a Multicriteria Decision Support System Adapted to Multiple-Use Forest Management: Application to Forest Management at the Management Unit Level in Southern Belgium

E. Bousson

Faculté universitaire des Sciences agronomiques
Gembloux, Belgium

Abstract

The main goal of this research is to develop a decision support system (DSS) applied to integrated forest management. This DSS consists of an evaluation and a multicriteria comparison of management alternatives at the management unit level. A modelling system has been elaborated to generate integrated forest management alternatives. Scenario modelling aims at describing the stand evolution and predicting the outcome of management alternatives and their consequences for the forest characteristics. Criteria concerning all the functions that forests could fulfil are used to assess alternatives. A multicriteria decision making method is finally used to compare management alternatives. This methodology is applied to integrated management of forests in the southwest of Belgium.

Keywords: integrated forest management, multicriteria decision-making technique, decision support system

1. Context and Objectives

For some years, forest has been increasingly considered as a shared property, used for nature conservation, landscape conservation, hunting and recreation. Besides, a growing number of stakeholders want to participate in the management of (near-)natural areas because these natural areas are considered as a natural heritage (Barthod and Ollagnon 1993; Schütz 1995; Barthod 1996). Forests, usually managed for timber production, have to serve other purposes, which express either the economic, ecological or social needs of our society. Forest management has to

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respond to these various and sometimes conflicting needs and managers need a suitable management framework (Barthod 1995; Guerin 1995). Within this context, a decision support system adapted to integrated forest management seems to be very worthwhile.

The main goal of this research is to develop a decision support method adapted to integrated forest management. Such a management approach takes into account both the functions that forests should fulfil, and also the involved stakeholders' opinions about the functions to focus on (Rameau 1995; Gauberville 1998). More and more, this means that several actors want to be involved in the management decisions. As a consequence, conflicts often appear and the negotiation process should be an efficient way to finally select a management alternative from all the possibilities. The forest manager needs to reconcile all the interests that forests represent (Thiollay 1997; Germain and Floyd 1999) and under these circumstances, they have to find the best compromise between a set of forest management scenarios.

The decision support method that we propose here uses multicriteria decision-making (MCDM) techniques, and more specifically the ELECTRE III method. These techniques are particularly suited for approaching this kind of complicated problem (Howard 1991; Maystre et al. 1994).

2. The MCDM Techniques

2.1 The payoff matrix

MCDM techniques are suitable for comparing potential solutions to a multicriteria problem when subjectivity of decisions is admitted. It means that the opinion of the decision-maker is very significant when choosing between a set of alternatives. As a matter of fact, there is objectively no optimal solution and the analysis provides some recommendations, some decision support to reach a compromise between several potential alternatives (Shärlig 1985; Roy 1992; Joerin 1998). The payoff matrix is the central element of a MCDM analysis (Table 1).

Table 1. Example of payoff matrix.

Criteria	C_1 Qualitative Index 0–1	C_2 Qualitative Index 1–10	C_3 Quantitative m³	….	C_m Quantitative
Set of Weights A	40	10	20	…	20
Alternative 1	0.56	8	1000	…	7000
Alternative 2	0.98	2	1400	…	10 000
Alternative …	…	…	…	…	…
Alternative n	0.32	7	900	…	5000
Trend	Maximise	Maximise	Maximise	…	Minimise

To build such a matrix, it is necessary to evaluate each alternative regarding each criterion and it is probably the most important step in the process. Alternatives (management scenarios) are included as rows and criteria as columns. The evaluation relates to the consequences of each alternative regarding each kind of goal, interest or criterion. The preference scale usually follows either a maximising or a minimising trend, sometimes an optimising trend. To build the payoff matrix objectives need to be clarified by the actors involved, and then criteria related to these objectives have to be defined. Three properties have to be respected to choose the criteria

(Shärlig 1996). First, they must be exhaustive so that each kind of interest is represented. However, they should not be redundant, otherwise they would be given more importance than the non-redundant ones. Finally the criteria must be coherent with the opinion of the stakeholders. The actors also have to identify and describe potential actions. The case study presented in section 4 illustrates these steps with an integrated forest management issue.

Moreover, it is clear that different actors will have different points of view about the priority to give to each kind of goal. Preferences from stakeholders have to be obtained regarding each criterion: the weights, which express the relative importance of the criteria, are provided by the stakeholders, and are included in the second row of the matrix. So, after working out evaluations, the first step is to express the opinion of the stakeholders with sets of weights assigned to the criteria.

2.2 The comparison process

The second step is the comparison itself. With an integrated management issue, several criteria used to evaluate the scenarios are qualitative, other ones are quantitative, they may be cardinal or ordinal, and therefore, they cannot be altogether aggregated, using the weighted average for instance, without losing important information about the weaknesses and strengths of the scenarios. Some MCDM techniques such as ELECTRE III provide the opportunity to compare evaluations without a complete aggregation. ELECTRE III is a partial aggregation method, which gives a ranking of the compared alternatives. The fundamental principles of this method are the following (Maystre et al. 1994; Shärlig 1996).

The alternatives are compared in a pairwise analysis, regarding each criterion and according to their weights. To take into account the gradation in the preference between two evaluations, thresholds have to be defined for each criterion as tools used in the pairwise comparison. These are the indifference threshold (q), the preference threshold (p) and the veto threshold (v). As long as the difference between two evaluations stays under the indifference threshold, there is indifference between the two alternatives regarding the criterion considered. When this difference ranges from the indifference threshold to the preference threshold there is a weak preference for one alternative. When the difference is beyond the preference threshold there is a strong preference for one alternative. The third threshold is the veto threshold. It is used to exclude one alternative where one evaluation is too bad, although the other ones accord with the global preference of this alternative compared with the other alternatives. On this basis, indexes are calculated for each pair of actions. The first index assesses how the evaluations are according to the preference for one action over another. This is the global agreement index:

$$C_{12} = \frac{\sum_{j=1}^{m} W_j \cdot c_j(a_1, a_2)}{\sum_{j=1}^{m} W_j}$$

where: C_{12} = global agreement index related to: alternative 1 is as good as alternative 2;
m = number of criteria;
W_j = weight of criterion j;
$c_j(a_1, a_2)$: local agreement index related to: alternative 1 is as good as alternative 2 regarding criterion j.

The local agreement index is dependent on the thresholds according to Figure 1.

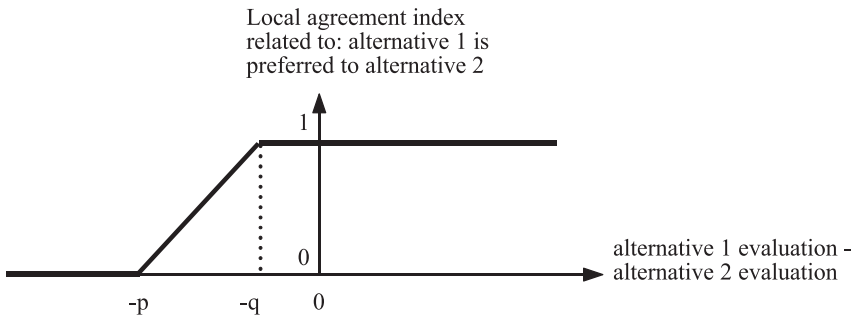

Figure 1. Illustration of the local agreement indexes.

The disagreement indexes measure, for each criterion, how some evaluations can conflict with this global preference, according to Figure 2.

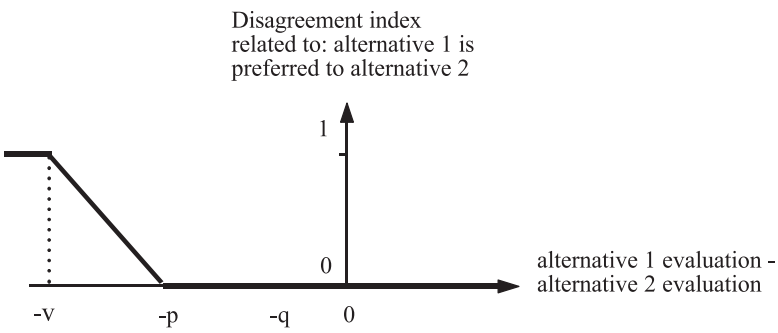

Figure 2. Illustration of the disagreement indexes.

The combination of these indexes is used to determine the credibility of prefererence of one alternative over another alternative:

$$\delta_{12} = C_{12} \cdot \prod_j \frac{1 - d_j(a_1, a_2)}{1 - C_{12}} \qquad \forall \text{ j such as } d_j(a_1,a_2) > C_{12}$$

where: δ_{12} = credibility degree related to: alternative 1 is as good as alternative 2;
C_{12} = global agreement index related to: alternative 1 is as good as alternative 2;
$d_j(a_1, a_2)$: disagreement index related to: alternative 1 is as good as alternative 2 regarding criterion j.

The credibility degrees are calculated for each pair of alternatives. Then it is possible to apply a classification process to the set of alternatives. The process is too complex to explain here.

However, interested readers can refer to some specialised publications (Shärlig 1985; Shärlig 1996; Maystre et al. 1994; Maystre and Bollinger 1999). Computers are used to achieve this last step of the comparison. We think it is more interesting to focus on the results and their interpretation.

2.3 The results

Synthesis information is provided in terms of a scenario ranking from the best to the worst. The results can be presented in a chart (Figure 3) (Simos 1990).

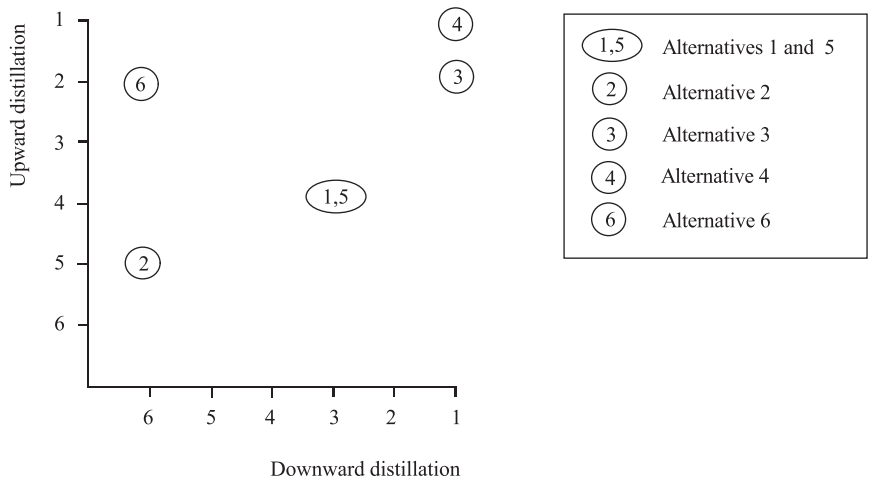

Figure 3. Results of the scenario ranking process.

Actually, two processes, called upward distillation and downward distillation, give two different classification results. With upward distillation, the scenarios are classified in an upward order, from the worst to the best. Downward distillation classifies the scenarios from the best to the worst. The scenario positions in these final classifications are reported on the X-axis and Y-axis. The best scenarios are located at the top right, the worst at the bottom left. The scenarios located on the diagonal obtain the same classification with the two processes. Their classification can be considered as strong. The classification of the other scenarios, which are located further away from the diagonal, is less strong: the further a scenario is from the diagonal, the more its classifications are different depending on the process used. It means that the scenario cannot be easily compared with the others.

2.4 Comment

The results are related to the weights subjectively chosen by the stakeholders and the comparison can be repeated with each set of weights. Then the results give information for choosing a scenario or reaching a compromise, possibly after discussions and negotiation between the actors involved in the decision. The case study will probably help in showing how to take advantage of this kind of result.

3. Application to Integrated Forest Management at the Management Unit Level

3.1 The structure of the decision support system

We propose a decision support system (DSS) applied to integrated forest management based on multicriteria analysis. This DSS consists of an evaluation and a multicriteria comparison of forest management alternatives at the management unit level. The problem formulation is to choose between a set of possible management alternatives. Certainly, the reasons for the choice are the scenario's consequences, which could be predicted. To make such a choice, we propose to assess how the alternatives are able to achieve every goal using a set of criteria related to the objectives. In this process, all the alternatives are evaluated in the same way. This assessment is based on the supposed forest conditions after application of the scenarios. To achieve this goal, different steps have to be considered (Figure 4).

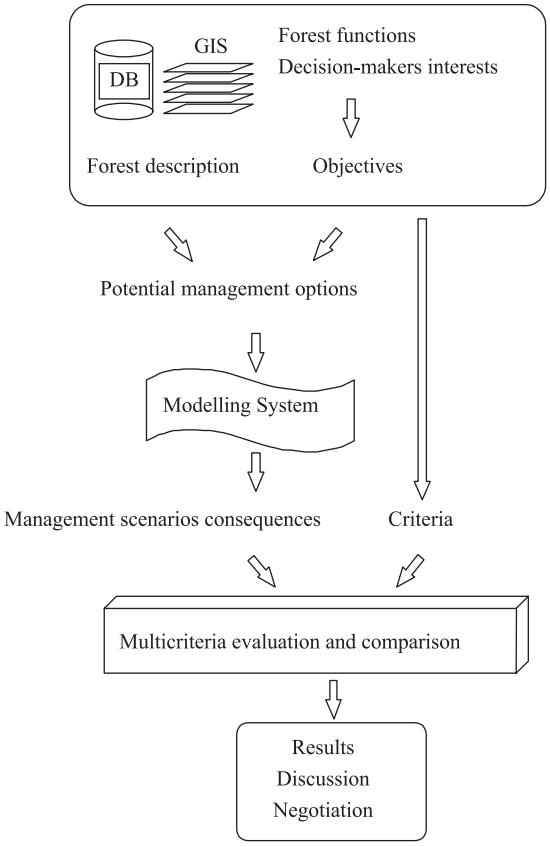

Figure 4. Structure of the decision support system.

First, management options result from knowledge of social and environmental constraints and possibilities. A modelling system has been developed to test the application of these management options. The scenario modelling aims at describing the stand evolution, and predicting the outcome of management alternatives and their consequences on the forest

characteristics. Then criteria that integrate, both the functions that forests should fulfil, and the stakeholders' opinions, are used to evaluate each alternative. This enables alternatives to be compared using a multicriteria decision-making technique. Multicriteria analysis enables the management options, which will reach a compromise, to be emphasised. Therefore, it provides an opportunity to choose a management alternative knowing its strengths and weaknesses in terms of every problem's facet or every actor's interests.

The MCDM technique focuses on the choice between some possible management scenarios. First, these alternatives have to be built by the stakeholders involved in the decision. A simulation software related to a descriptive database is necessary to test the management alternatives and it could, itself, be regarded as a decision support system.

Two main difficulties, which also represent the relevance of the method, have to be resolved. The first one is to define suitable criteria related to the objectives. The second one is to predict the outcome of each alternative.

3.2 Criteria definition

The criteria have to be related to the objectives. It means that the first step is the clarification of these objectives, by discussion between the actors involved in the decision process. We have identified five criteria families, which seem to be suitable for integrated management adapted to temperate multiple-use forests in a West European context:

- timber production criteria;
- ecological criteria;
- recreational criteria;
- game and hunting related criteria; and
- economic and financial criteria.

In each family, each criterion is related to a particular objective defined by the actors and indicators have to be derived to work out evaluations. For instance, in the family of timber production criteria, the tree population structure obtained by applying the management scenario is a criterion related to the objective of reaching a normal forest, in order to ensure sustainable yield. The indicator could be one that measures the margin between the observed age-class distribution and a regular age-class distribution. Another example is the harvested timber harvesting volume, used as an indicator of timber production.

With regard to the ecological criteria family, five criteria are defined at present. For instance, they concern the protection of rare or threatened species observed in the unit management. In the same way, the preservation of particular stands in the unit management is also considered, such as the habitat diversity at different spatial levels.

The last example concerns recreational criteria. Evaluation of the quality and length of the footpath network, which is planned in each management scenario, is chosen as an indicator related to the recreational management objectives.

3.3 Scenario modelling

Concerning scenario modelling, simulation models have to be developed in order to be able to predict the outcome of the scenario for every stand characteristic. The system needs growth models, but also models to simulate different kinds of phenomena (thinning, regeneration, etc.). For example, simulation software adapted to forest operation in mixed uneven-aged broadleaved stands, such as selective thinning and group cutting, has been

developed. However, hypotheses have had to be used because there was a lack of growth models adapted to this kind of stand. It shows that there are certainly opportunities to develop such simulation models, but some very basic tools are still missing to carry out this step fully.

Management operations related to recreation and forest conservation have also to be described in the formulation of the management alternatives to be compared.

4. Case Study

4.1 Description of the case studies

To test the technical feasibility of the proposed approach, case studies have been developed in Southern Belgium. Applying the method to public forests gave us the opportunity to achieve each step of the process. Actually, at present, some of these steps have not yet been fully carried out. First, the method has been partially applied to a public forest whose area is less than 100 ha, in the southwest of the Walloon Region (Figure 5). Only three criteria families (timber production, ecological and financial) have been considered and the stands were mainly mixed coppices stands. At present, the method is applied to a public forest which covers approximately 850 ha, whose stands are not only broadleaved stands (beech, oak), but also even-aged coniferous stands (especially spruce stands); the 5 criteria families listed above are considered in the different steps. To illustrate the application of the proposed approach, we will focus on the first case study.

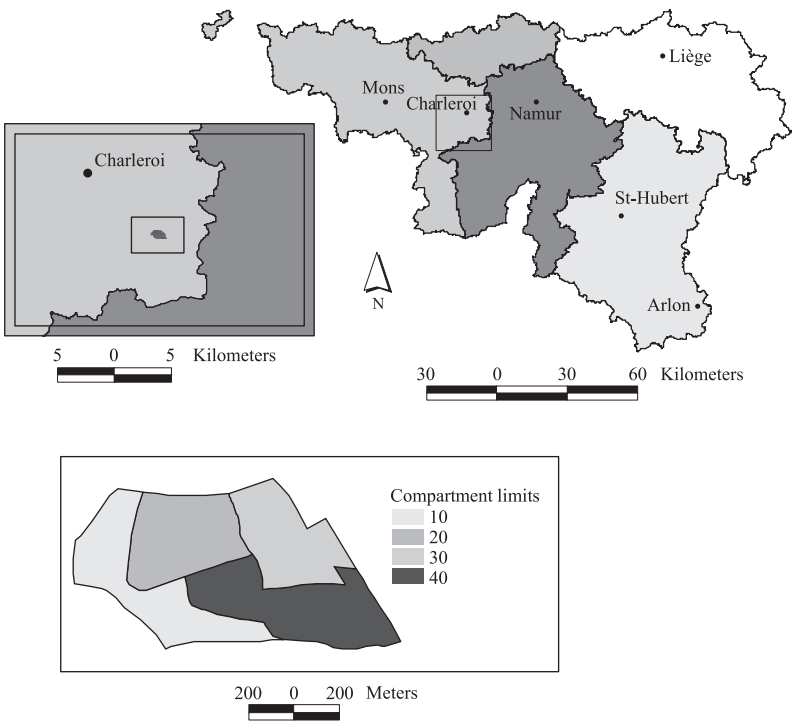

Figure 5. Localisation of the forest area in the Walloon Region.

4.2 Forest description

The first step concerns the forest description; it means that a set of thematic maps have been constructed, including the elevation model, the soil map, hydrology, etc. (Figure 6). GIS is a very useful tool to achieve this step.

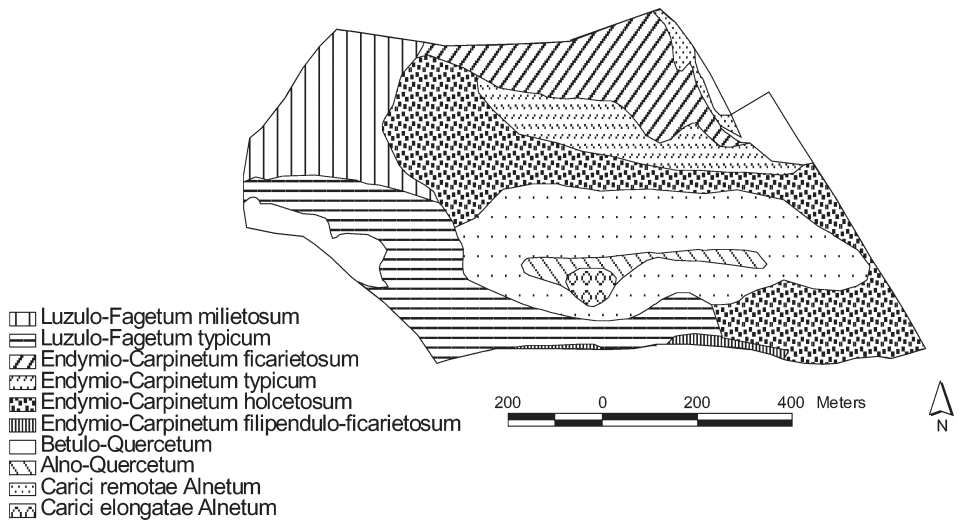

Figure 6. Soil potentialities expressed by the potential natural vegetation map.

Furthermore, an inventory is applied to each stand, in order to calculate the basic stand parameters (such as number of trees/ha, basal area/ha) and to describe the stands in terms of composition, stand structure (Figure 7), regeneration or coppices, according to the silvicultural system.

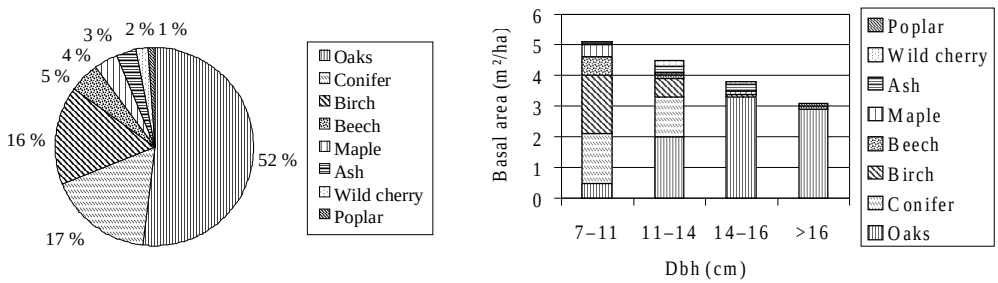

Figure 7. Species composition and structure of the high forest stands.

Moreover, a set of various data (e.g. log quality, game damage, or recreation facilities) can also be evaluated during the survey. This kind of data could be worthwhile when functions other than timber production have to be taken into account.

4.3 Construction and simulation of management options

Then, based on the present forest conditions, every actor involved in the process, including the forest manager, has to build and propose feasible forest management scenarios which are suitable for attaining some of the goals of integrated management. In this case study, scenarios have been built by the researcher to test the method suggested and the tools developed.

We are talking about forest management at the management unit level; so, the management scenarios are built at this spatial level over a period of about 20 or 30 years. It is important to emphasise the necessary correspondence between these space and time levels and the goal definition. In the Walloon Region, in particular, a management unit area usually ranges from 2000–3000 ha to less than 250 ha. The goals have to be defined at the operational level, and have to be related with the strategic objectives defined at a higher level, for instance, concerning ecological or recreational goals, especially when the management unit is very small.

Building a forest management scenario certainly means planning every silvicultural operation such as thinning, clear cutting and also planting. Many options have to be chosen in terms of type, weight and intensity of thinning, localisation of clear cutting and plantations, and species to be planted. Moreover, some options concern the right time to implement each operation in the field. Four scenarios have been built focusing on these operations. The main guidelines used to build each alternative are summarised in Table 2. Recreational management decisions could be made, such as building recreational facilities or opening some footpaths. Some operations related to game management and hunting could also be integrated into the forest management scenario.

Scenario modelling software has been developed to predict the consequences of silvicultural operations on the stands' characteristics. As explained, some hypotheses must still be used, because of the lack of data describing the growth in mixed uneven-aged broadleaved stands, such as coppice with standards.

Table 2. Brief description of the four management alternatives.

Trends	Thinning intensity and type	Clear-cutting areas	Plantations areas	Species promoted
Capitalisation (C)	Very low intensity of mixed thinning	None	None	No species in particular
Harvesting (E)	Very intensive Low thinning	Large	None	No species in particular
Intensification (I)	Medium high thinning	Large	Large	Coniferous species to the detriment of oaks
Medium (M)	Medium mixed thinning	Medium	Medium	Beech, ash, maples to the detriment of oaks

4.4 Multicriteria analysis

When all the evaluations have been worked out, on the basis of the scenario consequences predicted by the simulations, they are synthesised into the payoff matrix (Table 3). It is obvious that it is usually difficult to choose a scenario because there are often conflicts between the goals

Table 3. Payoff matrix related to the case study.

Criteria	**Timber prod.** Sustainable harvesting	**Timber prod.** Diversity of products	**Ecological** Species heterogeneity	**Ecological** Structure heterogeneity	**Financial** Benefit -Cost
Units	Basal area by age class: Shannon Index (min)	Sum of square of deviates between objective and result (min)	Cartographic Index 0–1 (max)	Cartographic Index 0–1 (max)	(max)
Scenarios					
Capitalisation (C)	–1.371	50.9	0.174	0.287	10 431
Exploitation cutting (E)	–1.254	20.4	0.165	0.268	20 810
Intensification (I)	–1.403	21.9	0.181	0.268	15 860
Medium (M)	–1.379	14.0	0.206	0.274	14 858
Trend	Max.	Max.	Max.	Max.	Max.
Set of Weight 1	10	10	10	10	60
Set of Weight 2	5	10	40	40	5
Set of Weight 3	20	20	20	20	20
Threshold q (indifference)	0.005	2	0.020	0.020	500
Threshold p (preference)	0.020	5	0.050	0.050	1000
Threshold v (veto)	0.200	30	0.500	0.500	10 000

to be achieved. That is why multicriteria analysis is used. Three sets of weights have been used in the comparison process, the results of which are discussed below. They represent some different possible opinions about the relative importance of the multiple objectives.

The results are reported in three charts (Figure 8). It is clear that they are highly dependent on the set of weights used. This focuses on the importance of the opinion of the decision-makers in the process. Besides, it also seems that if the same relative importance is accorded to the criteria, it could be difficult to identify a scenario with a strong ranking because of the lack of comparison between the scenarios. It means that it is not possible to determine whether one scenario is preferred to another. The first one could be preferred from the point of view of timber production, and the other one could be preferred from the point of view of ecological criteria. It is not possible to reach a decision about them. Thresholds are clearly related to this matter, and they must be chosen with care. For instance, the results of the comparison, using the third set of weights and a new set of thresholds, such as the one presented in Table 4, clearly point to one scenario (Figure 9).

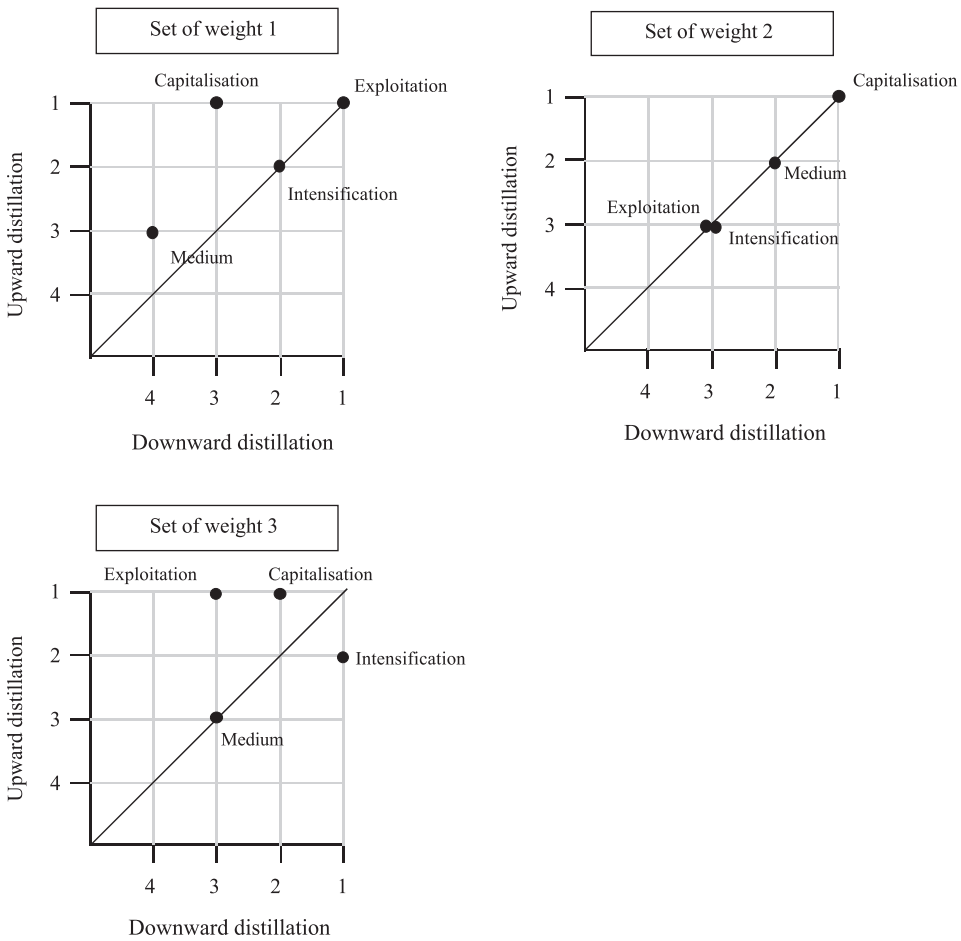

Figure 8. Results of the comparison process related to three sets of weights.

Table 4. New set of thresholds used with the third set of weights for a new comparison.

Criteria	Timber prod. Sustainable harvesting	Timber prod. Diversity of products	Ecological Species heterogeneity	Ecological Structure heterogeneity	Financial Benefit-Cost
Threshold q (indifference)	0.005	2	0.020	0.020	500
Threshold p (preference)	0.020	5	0.050	0.050	1000
Threshold v (veto)	0.200	50	0.100	0.100	20 000

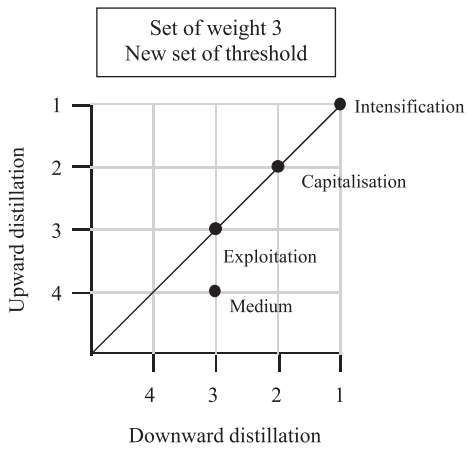

Figure 9. Results obtained with the new set of thresholds.

Discussions between the actors involved in reaching a compromise solution could focus on the relative importance of the criteria or on the thresholds to consider in the comparison. Besides, new scenarios could be designed by combining new possible actions. By using software to achieve the comparison process, they can be repeated as many times as necessary.

5. Conclusions and Perspectives

This decision support method gives decision-makers the opportunity to evaluate how a management scenario achieves the multiple goals of integrated forest management. To apply this method, it is necessary to clarify the objectives and to build some potential and feasible forest management alternatives. To this point, the payoff matrix is a very useful tool to support the decision. It is also definitely the most important step of the process. Furthermore, these first steps could help to resolve some potential conflicts between the stakeholders involved by clarifying objectives and predicting the consequences of the potential scenarios. On the other hand, the method enables alternatives to be compared, gives the opportunity to classify them from the best to the worst, and therefore, supports the choice among several possible scenarios.

The two main parts of the process are the criteria definition and the scenario modelling. In particular, the criteria need to be in agreement with the actors' interests to ensure the credibility of the results. Also, suitable models have to be available to predict the outcome of the scenarios proposed. There is still work to do on developing these models, but meanwhile, hypotheses have to be used.

This method based on MCDM techniques seems to be an interesting way to support decision-making in integrated forest management. The next complete application of this approach in the field should allow us to focus on the weaknesses and strengths of each step in the process in order to further improve the decision support system developed.

Acknowledgements

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Site Based Monitoring – How Many and How Long?

B. Farthing[1], T. Eyre[2], K. Mengersen[3] and P. Norman[2]

[1]Centre in Statistical Science and Industrial Mathematics (CiSSaIM)
Brisbane, Qld, Australia
[2]Forest Ecosystem Research and Assessment (FERA)
Brisbane, Qld, Australia
[3]Statistics, School of Mathematical and Physical Sciences, University of Newcastle,
Callaghan, NSW, Australia

Abstract

Monitoring presents foresters with a particular dilemma. Forests are very complex systems, of which our knowledge is incomplete. Changes are often slow and gradual and the trends for which we are monitoring are frequently disguised by stochastic noise. The fundamental questions faced by foresters are how many sites to measure, how often to measure them and for how long to measure them, before we can be confident of detecting any underlying trend. Statistical power analysis provides a tool that can be used to plan a monitoring strategy. Such analyses can be used to determine the approximate length of time that records must be made before trends are detected with appropriate levels of power, and the corresponding ground sampling plans at each time period. The costs of sampling and of elapsed time may be considered and incorporated in the sampling design. A preliminary investigation has focussed on reviewing trends in the development of habitat-bearing trees in forests of southeast Queensland. In this study it was found that sampling at 3 yearly intervals in 90 sites across 2.7 million hectares of forest will require 12 measure periods (or 36 years) to detect a decline of 2% per annum with statistical power of 95%. The study made use of the TRENDS (Gerrodette 1993) computer package and applied linear regression techniques to determine trends in a data series. With increasing acceptance of the need for monitoring forest environments, this provides a very useful tool for assessing the commitment required to meet such policies and for evaluating the true effectiveness of existing monitoring programs.

Keywords: monitoring, trend, power analysis, sampling strategy, Criteria and Indicators, sustainable forest management, Queensland

Alain Franc, Olivier Laroussinie and Timo Karjalainen (eds.)
Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level
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1. Introduction

The study of criteria and indicators for sustainable forest management naturally lends itself to long term monitoring plans with the aim of detecting trends in a quantity of interest. Statistical analysis of data from such plans can be achieved with time series techniques, which vary in complexity from autoregressive integrated moving average (ARIMA) models to linear regression models. These approaches relate the quantity of interest to the time of measurement, however they have differing assumptions concerning the amount of dependence that exists from period to period.

In the field, the researcher often needs to know how many sample sites to use and for how long they must sample to meet the needs of the monitoring program. Adopting a simple linear regression approach enables these questions to be answered with typically conservative estimates that are robust for small amounts of data. This modelling approach, in which the quantity of interest is regressed against time, has been considered by Gerrodette (1987) in a manner that enables the researcher to calculate the number of time points required to achieve an appropriate level of statistical power to detect a trend, if a trend exists.

This paper applies Gerrodette's methods to total estimates of habitat-bearing trees from a monitoring project in forests of southeast Queensland. An extension to the technique is then provided that allows the researcher to balance costs between the number of sites and the length of time to collect information.

The Forest Monitoring Plot Network (FMP Net) is an initiative of Queensland's Department of Natural Resource's (DNR) in response to the Montreal Process, where a network of long term monitoring sites are being established across broad forest types stratified by geology and management type.

The Montreal Process follows on from the UN Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992 and began when Canada convened an International Seminar of Experts on Sustainable Development of Boreal and Temperate Forests in September, 1993 (Montreal Process Implementation Group for Australia 1998, p.vii). The seminar focussed on the development of criteria and indicators for sustainable management of temperate and boreal forests.

This initiative led to the formation in June 1994 of the Working Group on Criteria and Indicators for the Conservation and Sustainable Forest Management of Temperate and Boreal Forests, also know as the Montreal Process Working Group. This group includes Argentina, Australia, Canada, Chile, China, Japan, Republic of Korea, Mexico, New Zealand, Russian Federation, USA and Uruguay.

In 1995, the Montreal Process endorsed a statement of political commitment to sustainable forest management. This was known as the 'Santiago Declaration' and included a comprehensive framework of seven criteria and 67 associated indicators that are to be used to monitor the sustainability of temperate and boreal forests around the world.

The indicators to be monitored by the FMP Net are:

1. Biological diversity.
   1.1. Area of forest type by growth stage distribution and tenure; and
   1.2. Population levels of representative species from diverse habitats monitored across their range.
2. Productive capacity and growth.
   2.1. Total growing stock of both merchantable and non-merchantable tree species on native forest land available for timber production;
   2.2. Annual removal of wood products compared to the sustainable volume; and
   2.3. Area and per cent of harvested area of native forest effectively regenerated.

3. Ecosystem health and vitality.
   3.1. Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality.
4. Soil resources.
   4.1. Area and per cent of forestland with significantly diminished soil organic matter and/or changes in other soil chemical properties.

The attributes measured at the sites include:

1. Standard measures – all trees >10 cm in diameter and all stags (i.e. dead trees) >20 cm are tagged, identified to species, diameter measured, assessed for merchantable form, length and limit, growth stage, crown score (i.e. a measure of a tree's crown characteristics) assessment, hollows count, and general tree/stand health;
2. Regeneration assessment – all trees within the selected area >2cm in diameter and >3m tall, and cover abundance of vegetation influencing effective regeneration;
3. Fallen woody material, ground cover and litter depth;
4. Soil survey – soil morphology profile and sampling for chemical analysis;
5. Floristics; and
6. Disturbance history – logging, treatment, fire and storm damage.

Eyre and Hardaker (unpublished) describe the methods and actual measurements that are taken at each site. It is planned to remeasure attributes every three years, or following a disturbance event such as logging or wildfire.

2. Theory

2.1 How long?

Gerrodette considered the use of linear regression (with and without a logarithmic transformation of the data) to detect trends in environmental abundance data (e.g. species of trees present). He determined a number of relationships that enables the researcher to conduct power calculations (see Appendix A) on the slope of the regression line. Each relationship assumes different combinations of the underlying model of change (linear or exponential) and the pattern of variation with respect to the total abundance estimate. Appendix B presents these relationships, and details on how they were derived may be found in Gerrodette's paper.

Given α (the probability of a Type I error or significance level), β (the probability of a Type II error), r (the rate of change per time period) and CV (the initial coefficient of variation) the researcher may use these relationships to calculate n (the number of samples to take over time) for their monitoring program. Mapstone (1995) provides a procedure for determining values of α and β that takes into account the costs of Type I and II errors. The r value should be set to a biologically significant value, as large monitoring programs could detect statistically significant trends that are not large enough to be relevant. A pilot study or past experience may be used to estimate the CV and to determine its relationship with abundance.

2.1.1 Effects of temporal autocorrelation

The presence of temporal autocorrelation can affect the accuracy of Gerrodette's relationships. If the autocorrelation is ignored and the data are analysed using ordinary least

squares (OLS) techniques (the basis of Gerrodette's relationships), biased estimates for σ^2 the residual variation) and $\sigma^2_{\hat{b}}$ (the variance of the OLS slope estimate) will be obtained. Appendix C provides details of this bias assuming that the autocorrelation structure arises from a first-order autoregressive (AR1) process. As Gerrodette uses a biased estimate of $\sigma^2_{\hat{b}}$ to determine his relationships, an under or overestimate of *n* will be obtained.

The direction and size of this error depends on the size of the autocorrelation coefficients, *n* and the covariate values in the regression. If we assume an AR1 model and covariate values of $(0,1,...,n-1)$, then negative values of ρ (the parameter in an AR1 model) will produce overestimates for *n* and positive values result in underestimates. Figure 1 illustrates this error for an example in which α, β, *r* and *CV* have been set to 5%, 5%, –2% and 0.386 respectively.

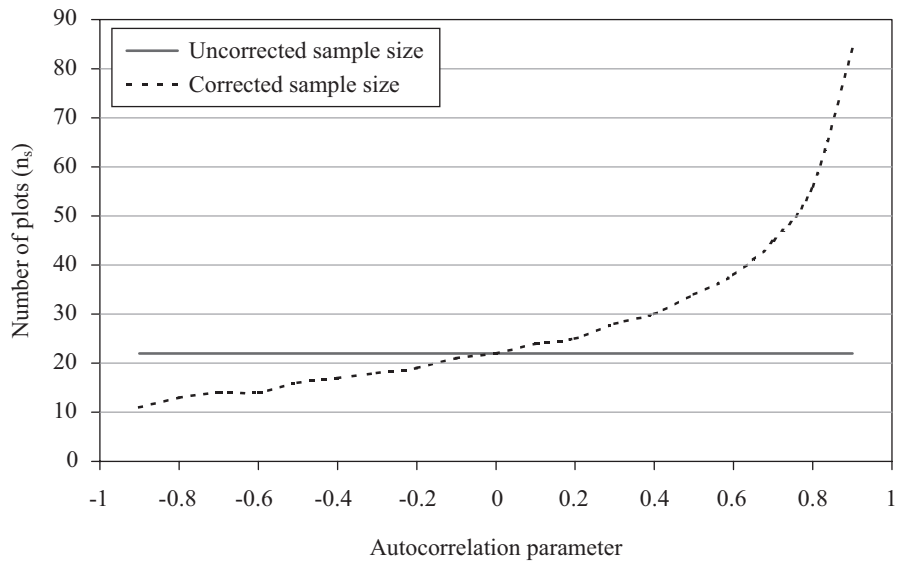

Figure 1. Effects of autocorrelation.

Gerrodette's relationships are thus conservative in the presence of negative autocorrelation as *n* is overestimated and power should be at least that specified. As positive autocorrelation results in an inaccurate estimate of the number of samples to take over time, it requires a different modelling approach (i.e. generalised linear or ARIMA models. See, for example, Judge et al. (1988)), or a post-hoc adjustment based on the size of the autocorrelation, or a longer period of time between samples. Equation 11 of Appendix C could be used to calculate this post-hoc adjustment. In practise it is unlikely that the actual value of any autocorrelation present is known making this adjustment difficult.

2.2 How many?

Power calculations are affected by the number and variability of observations in the sample. Reducing the variation in a sample or increasing the number of observations will increase the

power of a hypothesis test. The power is also increased if the significance level a is decreased or the size of the trend *r* that is required to be detected is increased. This knowledge can be used to help design the ground sampling plan.

In the case study presented in this paper, the variance of the total abundance estimate at any one time period is given by the following equation.

$$Var(A_i) = \frac{N_s^2}{n_s} Var(a_i) \qquad (1)$$

where: $Var(A_i)$ is the variance of the total abundance estimate at time *i*.
N_s is the potential sample size that may be used to obtain the total abundance estimate.
n_s is the size of the sample used to obtain the total abundance estimate.
$Var(a_i)$ is the variance of the observed abundance at time *i*.

This shows that, given an accurate estimate of $Var(a_i)$, the standard error of the total abundance estimate may be reduced by increasing n_s. In turn, reducing the standard error of the total abundance estimate enables the researcher to decrease *n* for any given values of α, β and *r* in Gerrodette's relationships. Similar inferences may be established with other statistics (e.g. the sample mean) depending on the researchers needs.

If costs are assigned to the establishment and subsequent remeasures of a monitoring site, the following function can be used to calculate a sampling plan's total projected cost (*PC*) for given values of n_s, α, β and *r*.

$$PC = n_s c \left\{ \frac{f\left[(1+j)^n - 1\right]}{j} - (f-1) \right\} \text{ when } j > 0 \qquad (2)$$

where: *c* is the cost to establish a monitoring site.
f is the remeasure costs of a monitoring site as a fraction of *c*.
j is the inflation rate.

The researcher determines values for *c* and *f* within their budgeting framework. Values for *j* are set arbitrarily depending on economic constraints believed to influence future costs relevant to monitoring.

Given, (i) the type of Gerrodette's relationships, *α*, *β*, *r* and *CV* necessary to applying it; (ii) *c*, *f* and *j* of Equation 2; and (iii) intial values for *n* and n_s, it is necessary to solve the following system by iteration:

$n = f(n_s, \alpha, \beta, r, CV)$

$PC = f(n, n_s, c, f, j)$

To find the lowest *PC* for detecting a trend (for a given rate of change per time period), it is necessary to iterate the system. An increase in the number of sites sampled each time n_s reduces *CV* and results in a decrease of *n*, but not continuously, only step by step. So while *n* does not change, *PC* increases with n_s. When *n* decreases, *PC* decreases simultaneously, and so on until a minimum *PC* is found.

A plot of *PC* against n_s assists the researcher to choose a sampling plan to meet their power requirements at the minimum total projected cost.

3. Case Study – Habitat-Bearing Trees

3.1 Methods

We have investigated the number of samples per time period n_s and the number of time periods n necessary to detect trends in the abundance of habitat-bearing trees as measured by the FMP Net. Maintaining the levels of such trees is considered important for the biodiversity of the region, as many species of wildlife use habit-bearing trees for shelter.

An initial measurement of the number of habitat-bearing trees was made at 58 sites from the FMP Net in southeast Queensland (see Figure 2). These counts were made by visually inspecting all trees on the half-hectare sites for signs of hollows with an opening diameter greater than 10 cm. Total abundance estimates were calculated as $N\bar{a}$ where $\bar{a}$ is the mean number of habitat-bearing trees in the sample and N is the total number of sites measured in the initial study.

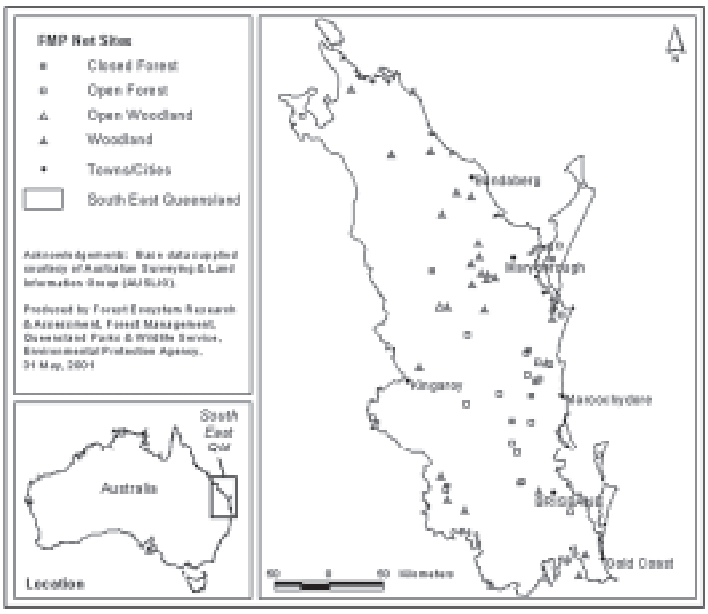

Figure 2. FMP Net sites.

The area under study has been broadly stratified into four forest types (closed forest, open forest, woodland and open woodland). These classifications were based on the projected foliage cover for an area, with densities of: 100–70% being closed forest; 70–50% being open forest; 50–30% being woodland; and 30–0% being open woodland.

Projected costs of four sampling plans were compared to determine the type of plan to use and the number of sites to measure at each time point. The first plan equally allocates the number of sites to each forest type. The second plan maintains the proportion of sites per forest type to that given by the current sampling arrangement. The third and fourth plans respectively allocate the number of sites to each forest type in proportion to the area covered by the type and optimally depending on the variation in the number of habitat-bearing trees in a type. Table 1 summarises the four sampling plans.

Table 1. Sampling plans for comparison.

Plan	Allocation Method	Formula (if available)
One	Equal proportions of total sample per strata	$n_h = \frac{1}{4} n_s$
Two	Current sampling arrangement	
Three	Proportional (Cochran 1977)	$n_h = N_h \frac{n_s}{N_s}$
Four	Neyman (Cochran 1977)	$n_h = n_s \frac{N_h s_h}{\sum_{h=1}^{k} N_h s_h}$

where: n_h is the size of the sample in stratum h.
N_h is the potential sample size for stratum h.
s_h is the standard deviation of stratum h.
k is the total number of strata.

We can see that the expected sample size in a stratum under plans three and four follow two rules: the size is larger within a given stratum if the stratum is large and it is more variable internally.

The TRENDS computer package was used to calculate the n required to detect a declining trend of 2% per year with a 5% level of significance and 95% power for the differing *CV* values associated with increasing values of n_s. Each calculation was based on Gerrodette's relationship that assumes an exponential trend and a *CV* that is proportional to the abundance (i.e. inequality 6 in Appendix B).

An exponential trend model has been used for two reasons. The first reason was that most of the reductions in the number of habitat-bearing trees is thought to result from catastrophic events (e.g. severe storms, fire, etc.). Under this assumption, it is expected that fractions of the total number of habitat-bearing trees would be destroyed almost instantaneously. The graph of such a loss is better approximated with an exponential curve rather than a straight line. The second reason is that using the exponential model provides more conservative estimates (i.e. longer time periods to have to measure for a desired level of power).

The *CV* was assumed to be proportional to abundance after considering the theoretical statistical model commonly used with count data. This is the Poisson model and has a theoretical variance equal to the mean.

Projected costs for each plan using different values for n_s were calculated and graphed in Microsoft© Excel. These calculations were based on a setup cost of $5000 (AUD), an initial remeasure cost of $2000 (AUD) and an inflation rate of 6% per year. Setup and remeasure costs were estimated from past monitoring efforts by experienced DNR field staff. The inflation rate is arbitrary, presently reflecting the long term rate commonly used in an Australian economic costing.

3.2 Results

The small sample sizes for closed forests and woodland is reflected in the large standard error of the total abundance estimate.

Table 2. Summary of raw data.

Forest type	Number of plots (possibleplots)	Number of habitat-bearing trees	Sample mean	Sample standard deviation
Closed forest	8 (136 399)	45	5.625	9.591
Open forest	22 (277 376)	196	8.909	17.282
Woodland	26 (60 978)	161	6.192	9.209
Open woodland	2 (864 722)	4	2.000	2.828

Table 3. Abundance estimates.

Forest type	Total abundance estimate	Standard error of estimate
Closed forest	767 244	462 506
Open forest	2 471 168	1 021 985
Woodland	377 591	110 125
Open woodland	1 729 443	1 729 443
Total	5 345 447	2 064 332

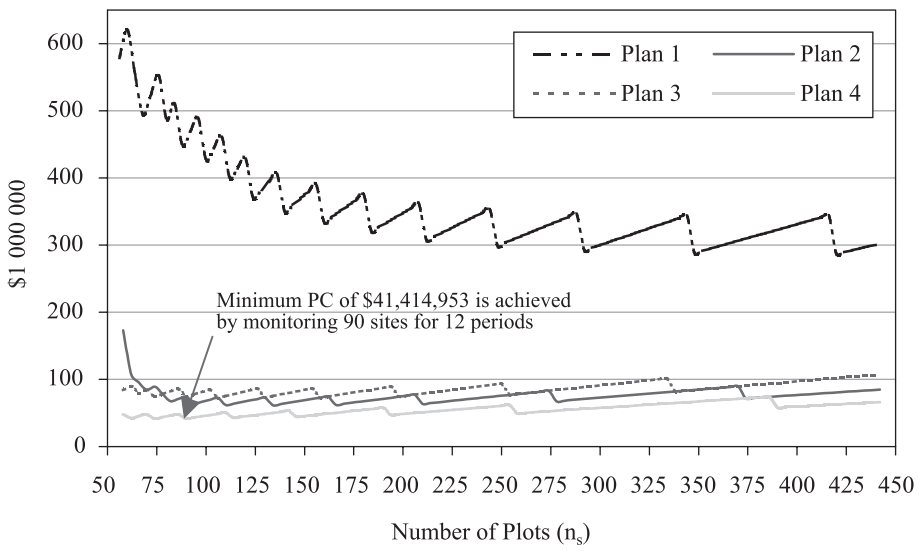

Figure 3. Projected costs of sampling plans.

The *CV* for this data set is 0.386. Using this value, the approximate length of time to measure under the present sampling arrangement is 66 years (equivalent to 22 measure periods as each period is equal to 3 years) and has a total projected cost of $173 336 652 (AUD).

Figure 3 illustrates the relationship between *PC* and n_s for each of the four sampling plans being considered. The jagged nature of the graph occurs as small increases in n_s do not alter

the *CV* sufficiently to reduce *n* in Gerrodette's relationships. This results in increasing costs until such time as the *CV* is small enough to decrease the value of *n*, at which point the costs drop to reflect a shorter time period being monitored. A second feature is the slightly concave nature of the graph for plans two, three and four (i.e. the *PC* stops reducing and then begins to increase after a threshold). This is due to the plans reaching a level that an increase in n_s provides insufficient additional information to offset the extra cost incurred.

Figure 4 illustrates the relationship between *n* and n_s for each of the four sampling plans being considered. Again, the jagged nature of the graph occurs as small increases in n_s do not alter the *CV* sufficiently to reduce *n* in Gerrodette's relationships.

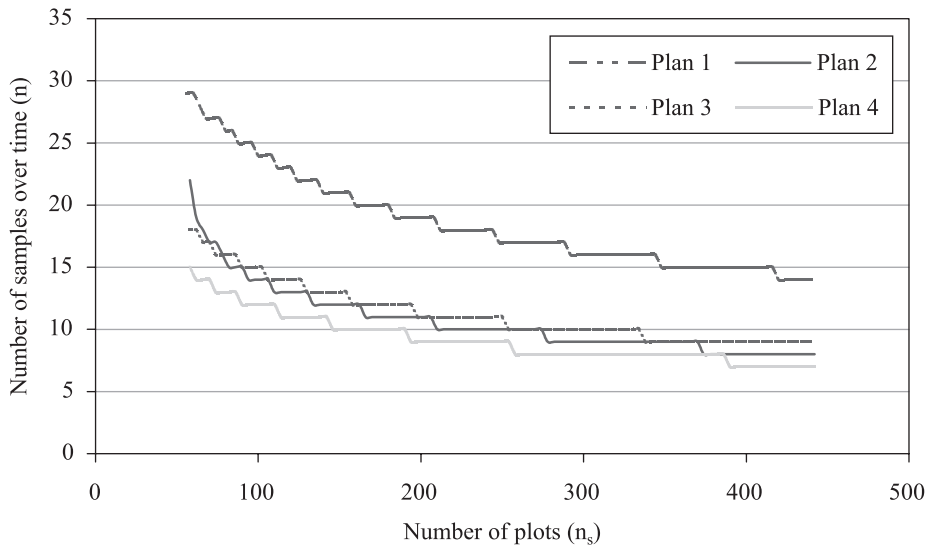

Figure 4. Number samples over time versus plots under each sampling plan.

3.3 Conclusions

Sampling plan 4 appears to provide the most cost effective arrangement. This is a result of increasing the sampling effort in areas of high variability that reduces the *CV* at a faster rate than seen in other plans. Under this plan the minimum projected cost (marked on Figure 3) of $41 414 953 (AUD) is achieved by monitoring 90 sites for 12 measure periods (i.e. 36 years). These 90 sites are allocated in the following manner: 13 in closed forests; 47 in open forests; 6 in woodland; and 24 in open woodland.

Sampling plan 1 was a poor design, costing between 4 to 11 times that of plan 4 with a similar number of total sites. Sampling plans 2 and 3 perform similarly when compared with plan 4, although plan 2 outperforms plan 3 at most points. This is a result of the current sampling plan having positioned more sites in areas of high variability, thus making it more in line with plan 4. Sampling plan 3 focused the sampling effort in the largest forest type, which has the least variable data, so the additional effort is not reducing the *CV* fast enough to produce the slightly larger gains seen with plans 2 and 4.

4. Discussion

The technique presented in this paper provides a typically conservative method to determine estimates of the number of sample sites and the length for which these sites need to be monitored. These values can be used as an aid in the planning of an environmental monitoring plan to detect trends in the abundance of a quantity of interest.

There are two concerns with this procedure. The first relates to the dependency on the accurate estimation of an attribute's true variability and the second involves the error introduced in the presence of temporal autocorrelation.

Increasing sampling effort in any study may often be used to reduce the variability in estimates calculated from the raw data. It does not remove, or even reduce, the underlying natural variation in the attribute being measured. The manner in which the *CV* reduces with greater proposed sampling effort in this paper assumes that the sample estimates of attribute variability truly reflect its natural variation. If this is so then increases in sample size shall not alter the estimate of the attribute's variability. Due to measurement error and other random influences, the sample variability from a pilot study may not be an accurate reflection of the expected variation as the sample size increases. This will result in changes in the *CV* that do not imitate what is modelled in the technique presented here. The researcher may prefer to augment the variance from the pilot study with allowances for these additional sources of variation, variability estimates from previous studies or personal knowledge of the attribute in question.

The presence of temporal autocorrelation will result in an under or overestimate of n when using Gerrodette's relationships. The level of any autocorrelation will often be linked to the periodicity of the measurements. This aspect of a sampling plan has not been considered in this paper. However, lengthening the time between measurements could be investigated to help remove or reduce any temporal autocorrelation. In the presence of negative autocorrelation the estimate is conservative and power should be at least that specified. Positive autocorrelation requires either a different modelling approach such as a generalised linear model and/or an ARIMA model or a post-hoc adjustment based on the size of the autocorrelation.

Although the concerns raised above are important, it must be remembered that this technique is proposed as a tool to assist in the *planning* of environmental monitoring programs. In most circumstances detailed knowledge of an attribute's variability is not available and information will be gained as the monitoring progresses. The incorporation of the power to detect trends ensures that plans are properly designed to detect true changes of interest with specified confidence. Determining time frames and sample numbers also allows the researcher to communicate to the stakeholders the extent of a program in order to track and report changes of concern. This helps to alleviate false hopes or disappointment at later dates when less well designed programs are found to be insufficient for their purpose.

Due to the dependencies between the variables in the analysis, a large number of iterative calculations had to be performed. This could be automated to greatly speed-up and improve the process of planning an environmental monitoring program. Current work is focussing on the development of an appropriate computing package to perform the necessary calculations and present relevant summary graphs and statistics for review by the researcher.

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Appendix A. Power Calculations and Hypothesis Testing

A statistical hypothesis is defined as an assertion or conjecture concerning one or more populations (Walpole and Myers 1993). The truth or falsity of the conjecture is not known with absolute certainty unless the entire population is examined. As this is usually too costly or impractical to do, the researcher takes a suitable random sample of the population and makes use of this data to accept or reject their original conjecture.

The acceptance of the original conjecture implies that the data is not sufficient to refute it, whereas rejection of the conjecture means that there is a small chance of obtaining the data observed when, in fact, the conjecture was true. As a result, statistical hypotheses are usually termed in the negative, that is the conjecture made suggests the opposite to that which the researcher wishes to prove. In this manner, rejection of the conjecture establishes a stronger conclusion by the researcher.

In statistical terms, the conjecture to be disproved is known as the null hypothesis. When testing the null hypothesis, a test statistic is derived from the data collected (having regard for the processes thought to drive the data, the data itself and its' method of collection) and this is compared to a critical value. Setting of the critical value determines an acceptance and a rejection region. If the test statistics falls within the acceptance region the null hypothesis is accepted, otherwise it is rejected.

When accepting or rejecting a null hypothesis, two errors may be made (due to the uncertain nature of the true values being tested). The first such error, termed a Type I error and denoted by a, occurs when the null hypothesis is incorrectly rejected. The second error, termed a Type II error and denoted by b, occurs when the null hypothesis is incorrectly accepted. The value *1*-b is known as the power of the test. The researcher has some control over the chance of making these errors. In the first instance, this control is explicit as the researcher sets the probability of a Type I error to a level deemed to be satisfactory. This level has traditionally been set at 5% (Burgman et al. 1998; Gray 1990; Green 1995; Mapstone 1995; Peterman 1990). In the second instance, the probability of a Type II error can be controlled implicitly by relaxing the value of a, increasing the size of the sample or the level of the effect to be detected, or by reducing sample variability.

In terms of environmental impact assessment the power of a hypothesis test is the ability to detect a prespecified effect given that such an effect has occurred (Burgman et al. 1998; Green 1995). Power calculations may be performed *a priori* or *a posteriori* to an experiment or observational study in question and involves the following five variables:

1. Significance level of the test, also know as a Type I error (α);
2. Probability of a Type II error (β);
3. Effect size (δ);
4. Sample size (n); and,
5. Sample variation (s^2)

Appendix B. Gerrodette's Power Relationships for Linear Regression

The following inequalities all use a null hypothesis stating that the slope of the regression line is zero (i.e. no trend exists) and an alternate hypothesis stating that the slope equals r times the initial abundance value (linear model of change) or it equals ln(1 + r) (exponential model of change). One modification arises when the null hypothesis is one-tailed (e.g. slope is less than or equal to zero). In this situation $z_{\alpha/2}$ is replaced by z_{α}.

Linear trend with CV proportional to abundance:

$$r^2 n(n-1)(n+1) \geq 12CV^2 (z_{\alpha/2} + z_{\beta})^2 \left[1 + \frac{r}{2}(n-1)\right] \qquad (3)$$

Linear trend with CV proportional to abundance squared:

$$r^2 n(n-1)(n+1) \geq 12CV^2 (z_{\alpha/2} + z_{\beta})^2 \left\{1 + r(n-1)\left[1 + \frac{r}{6}(2n-1)\right]\right\} \qquad (4)$$

Linear trend with CV proportional to abundance cubed:

$$r^2 n(n-1)(n+1) \geq 12CV^2 (z_{\alpha/2} + z_{\beta})^2 \left\{1 + \frac{3r}{2}(n-1)\left[1 + \frac{r}{3}(2n-1) + \frac{r^2}{6}n(n-1)\right]\right\} \qquad (5)$$

Exponential trend with CV proportional to abundance:

$$[\ln(1+r)]^2 n(n-1)(n+1) \geq 12(z_{\alpha/2} + z_{\beta})^2 \left\{\frac{1}{n}\sum_{i=1}^{n} \ln\left[\frac{CV^2}{(1+r)^{i-1}} + 1\right]\right\} \qquad (6)$$

Exponential trend with CV proportional to abundance squared:

$$[\ln(1+r)]^2 n(n-1)(n+1) \geq 12(z_{\alpha/2} + z_{\beta})^2 \left[\ln(CV^2 + 1)\right] \qquad (7)$$

Exponential trend with CV proportional to abundance cubed:

$$[\ln(1+r)]^2 n(n-1)(n+1) \geq 12(z_{\alpha/2} + z_{\beta})^2 \left\{\frac{1}{n}\sum_{i=1}^{n} \ln\left[CV^2(1+r)^{i-1} + 1\right]\right\} \qquad (8)$$

where: r is the rate of change per time period of the quantity being measured.
n is the number of samples taken over time.
z_{α} is the value of the standardised random normal variable such that the area under one tail of the probability density function beyond z_{α} is α (some researchers may wish to use a non-central t distribution in place of the standardised normal distribution for circumstances when the number of time points is low).
CV is the coefficient of variation at the first measurement.

The values of r and CV are calculated by taking the proportions of δ and s with the initial abundance estimate for the attribute under study.

The researcher should choose an inequality that satisfies their assumptions regarding the process being modelled. For example, if it was believed that the rate of change of an abundance measure was linear and that the CV of the abundance estimate at each time point was a proportion of the estimate, then inequality (3) would be used for any power calculations.

Appendix C. Effects of Temporal Autocorrelation

Equations 10 and 11 show the expected value of s^2 (an estimate of the residual variance) and the variance of the OLS slope estimate assuming the first-order autoregressive model:

$$\varepsilon_i = \rho\varepsilon_{i-1} + \delta_i \qquad (9)$$

where: ε_j is the jth error term.
$|\rho| < 1$ and is the autocorrelation at lag 1.
δ_i is an independent random normal variable with mean zero and constant variance σ_δ^2

Expected value of the residual variance:

$$E\left(s^2\right) = \sigma_e^2 \left\{ 1 - \frac{2}{n(n-2)(n-1)(n+1)} \sum\sum_{i<j} \left[n^2 - 1 - 12\left(x_i - \frac{(n-1)}{2} \right)\left(x_j - \frac{(n-1)}{2} \right) \right] \rho^{j-i} \right\} \qquad (10)$$

Variance of the OLS slope estimate:

$$\sigma_{\hat{b}}^2 = \frac{12\sigma_e^2}{n(n-1)(n+1)} \left\{ 1 + \frac{24}{n(n-1)(n+1)} \sum\sum_{i<j} \left(x_i - \frac{(n-1)}{2} \right)\left(x_j - \frac{(n-1)}{2} \right) \rho^{j-i} \right\} \qquad (11)$$

where: σ_e^2 is the error variance.

The Use of Predictive Models of Breeding Bird Assemblages for Assessing and Monitoring Forest Bird Diversity

Jean-Luc DesGranges[1], Patrick Agin[2] and Samy Bengio[2]

[1]Canadian Wildlife Service, Sainte-Foy, Quebec, Canada
[2]Institut de recherche en modèles adaptatifs

Abstract

Two types of learning algorithms, artificial neural networks and bin smoothers, were used to develop models for predicting bird assemblages, species richness and avian density in forests, based on two sets of geographic and forest variables. Such predictions very likely constitute indicators of avian biodiversity, itself an indicator of overall biodiversity, which is essential information in assessing the condition of commercial forests. The models perform a range of predictions, from the simple presence or absence of species to accurate forecasts of species densities. They use variables obtained not only from detailed forest inventories, but also from the basic classification of satellite images. Although, for most problems and bird species, the models performed better than ornithologists familiar with the birds in the forests studied (northeastern North America), no model was consistently better than the others at every problem. Rather than using only the model found to be the best in this study (smoother trained with 23 environmental variables), it is recommended that the predictions made by the different models be combined, which would increase the robustness of the models by decreasing variance. The methodological advances presented in this paper, i.e. the use of different performance indicators of models and the use of several models in parallel, could be used profitably for other taxonomic groups if data are available.

Keywords: biodiversity evaluation, bird assemblages, forest certification, indicators modeling

Introduction

Today, the forest environment and forest resources are being used to an ever-greater extent. In view of the economic importance of Canadian forests and the essential role they play in the

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survival of numerous wildlife species, it is imperative that increasingly effective practices be implemented to manage forest vegetation. Therefore, forest managers must examine the characteristics of all environmental components and measure their interdependence in their planning, to ensure that an intervention directed at one component will not have an adverse impact on other resources. Improving our ability to manage forests ecologically will depend largely on advances in the area of knowledge-based systems. We need to develop operational, computer-assisted forest resource models that can be used to generate intervention scenarios that are likely to optimize the yield of a given area and utilize the primary components more effectively.

Recognition and preservation of forest biodiversity are the best route to sustainable development. Consequently, we need to develop and use biodiversity indicators that are meaningful and practical for managing large tracts of forest land. Since it is impossible to survey all the living species in a given environment, multi-species assemblages should be used as bioindicators. Since birds occupy an important place in the forest ecosystem, the presence and abundance of avian species alone should provide a good indication of the biological quality or viability of the forest and hence the extent of biodiversity.

Furthermore, given the need for georeferenced digital data at the ecosystem and regional landscape scales, models that harness satellite imagery must be developed. Recent advances in remote sensing enable us to identify forest habitat types and structural aspects that have an influence on avian communities. By drawing on these data and appropriate expertise, it should be possible to create a model that can predict the avian components of various forest habitats and characterize the avian biodiversity of a given forest environment.

The data used for model training

The bird survey data used in training the models came mainly from the North American database of the National Biological Survey Inventory & Monitoring Service (MD-USA). This database contains all the Breeding Bird Counts (BBC) published in the magazine ‘American Birds’ since the 1930s, and other unpublished census data from the USA and Canada. We enriched this database with a large number of bird counts conducted in Eastern Canada and northeastern USA, and published in various journals or technical documents since the 1940s. Bird count and density data obtained through different survey techniques, with the exception of transects, were accepted. To this end, a method for converting relative abundances into bird densities was developed for the different field survey methods employed (see Poulin and DesGranges 1998). Figure 1 shows the distribution of the accepted counts in the ecological regions of Quebec and in the adjoining Canadian provinces and USA states.

Not all the data collected was relevant to creating the models. The information fields used in the database are described in Poulin and DesGranges (1998). Only avian and plant species found in Quebec (indigenous or cultivated) were included, and habitat description was complete enough for 1899 counts. The database used for modeling, contains 162 breeding bird species found in Quebec. The plant species observed on the sites were classified according to their dominance or relative abundance in the three vertical strata of vegetation: the canopy or tree layer; the shrub layer; and the ground-level or herbaceous layer. More than 56 tree species were identified in the tree layer, 94 shrub or small tree species in the shrub layer, and 99 herbaceous species in the ground layer. Open areas with sparse vegetation, made up about 50% of the counts in the database. Of the censuses conducted in dense forest, 19% were in deciduous forest, 14% in mixed forest, and 16% in coniferous forest. The majority of counts revealed the presence of disturbances. Clear-cutting (18%) was the predominant major disturbance affecting forest land, followed by insect outbreaks (8%) and

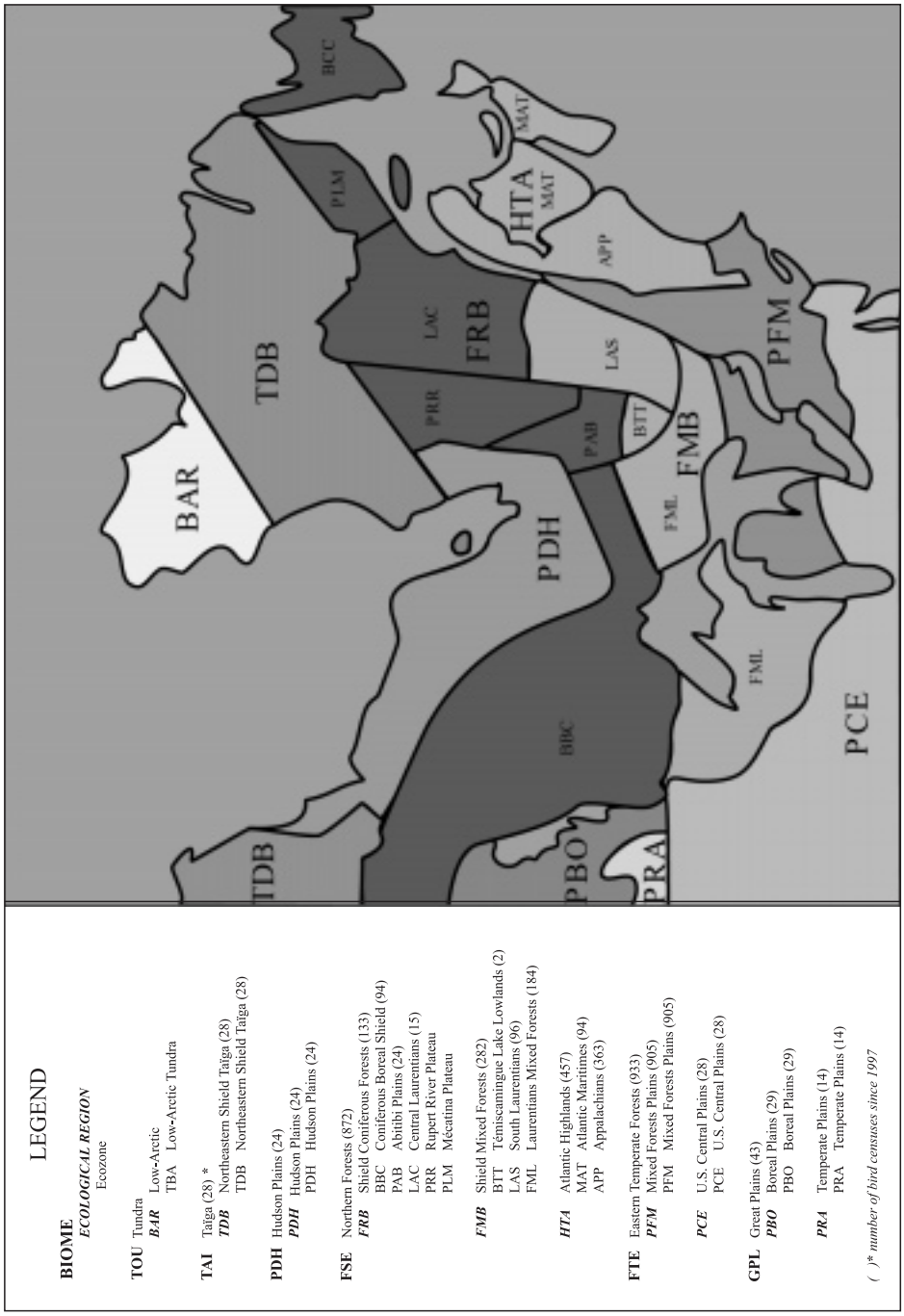


Figure 1. Geographical location of ecological regions and distribution of bird censuses used for the training of models.

partial cutting (7%). In addition, a large portion of the surveyed sites were located in fragmented forests in the urban (13%) or agricultural (9%) environment.

Modeling problem

The problem, as initially posed, involves establishing a model for predicting avian density based on environmental variables. Species density prediction can be tackled from various standpoints depending on the purpose at hand. For example, whereas detailed density predictions might be the goal in some studies, in other cases the goal may be to obtain less refined results from the model, but higher quality predictions. In the present study, we deal with three aspects of this issue:

1. prediction of species density by using a continuous variable that can have values from zero to infinity.
2. prediction of species presence by using a discrete variable for which there are only two possible values: 0 for absence; 1 for presence.
3. prediction of the abundance class of a species by using a discrete variable that can have one of four values: 0 for absent; 1 for rare; 2 for frequent; and 3 for common.

The problem as stated in (1) entails regression, whereas the other two are classification problems. In general terms, classification problems map inputs to a discrete set of outputs and regression problems map inputs to a continuous set of outputs. Note, however, that it is possible to solve a classification problem using a regression algorithm (but this might not be the best solution), while, in general, the converse is not true.

All three problems may call for different models depending on the type of models used to solve them, i.e. semi-parametric or non-parametric.

Artificial neural networks are essentially a non-linear extension of classical linear regression models. They are semi-parametric models that include numerous parameters and that make few assumptions about the form of the sought-after function. They can be used to express relationships of arbitrary complexity by superimposing linear and non-linear functions. Simple optimization algorithms, such as gradient descent or conjugate gradient algorithms, are used to establish the parameters of such models (Herts et al. 1991; Bishop 1995).

All of the training data have to be presented several times so that the connection weights of the neurones can stabilize at a level suitable for classification. When properly trained, a neural network is able to recognize patterns in data similar to the original training information. Completely new data will not be recognized unless the network is retrained using the new values in conjunction with the old. If only new examples are presented, the network will forget the old ones. Information processing in the hidden layer involves correlating different inputs and outputs. As the network is trained with from multiple situations, it develops the capacity to generalize. The trick is to achieve just the right level of training to enable it to recognize known and similar patterns. An overtrained network memorizes the individual examples presented in training. Conversely, an undertrained network overgeneralizes and is unable to pick out even known cases. This modeling technique has been applied previously to clustering and patternizing community data in ecology (Chon et al. 1996; Weeks and Gaston 1997).

Another kind of a model, a smoother model (SM), was also used in this study. Smoothers are non-parametric models that differ from the models described above in that they make no assumption about the functional form of the relationship between the predictor variables and the predicted variables (Hastie 1990). Generalized additive models (GAM) allow a unified treatment of statistical methodology for several important classes of models. They can include as a specific

(and very simple) case the smoother. So simple, however, that it is more correct in our opinion to use the term smoother without referring to the whole family of GAM models.

To provide answers, this type of model processes only the data presented, which means that no real learning occurs. While this can reduce the time required for model development, the fact that no learning occurs means that all the data have to be stored in memory and more time must be devoted to computation during any later use of the model. For each new site that necessitates specifying whether a bird species is present or absent, the model searches the known samples to find those whose input variables (description of the environment) are closest to the present sample. All that remains to be done is to determine the nature of the function that, when applied to all the neighbours of a particular input, provides as output the model prediction for this input. A commonly used function is the arithmetic mean, as mentioned above. However, when a population of points has an asymmetrical distribution or includes a large number of extreme values, it may be advantageous to use a more robust statistic such as the median.

The important parameter in this type of model is that which defines the neighbourhood for each point in the input space. Clearly, if an overly large neighbourhood is selected, the data will be underadjusted, since the model's response will ultimately be the same, i.e. the overall mean of all the answers. The model smooths the data excessively by always giving the same answer, regardless of the input that is presented. Conversely, when an excessively small neighbourhood is selected, the data are overadjusted, since the model relies on a limited number of neighbours in order to come up with an answer. The smoothing function is reduced to a minimum when only one neighbour is considered at each input point (the mean of this neighbourhood that has only one element is obviously the answer). Therefore, it seems clear that, as with the semi-parametric models considered above, non-parametric models raise the issue of optimal capacity. For this reason, it is important to determine the optimal value of the smoothing parameter, since the latter defines the neighbourhood of all points and since this will ensure that the model generalizes effectively.

When the input variables consist solely of categories (like most variables related to the present problem), the simplest smoothing model consists in considering as neighbours of an input point only those points that belong to the same category. The smoothing level in such a case is established through the choice of variables – and the number of categories that each includes – used for comparisons. For example, given certain inputs, it would be possible to consider as neighbours all the points for which the ecological region is exactly the same as for the input. In this case, the smoothing level would be rather great since each input would comprise a relatively large number of neighbours (the nine ecological regions each include 34 182 points on average). By contrast, the degree of smoothing would be much lower if the only points considered neighbours were those for which the ecological region, ecozone and habitat type were the same as those for the input point (in this case, each triplet would only have about 15 points).

However, this type of model has a serious flaw, which is directly linked to the dimensionality of the system: dimensionality increases exponentially with the number of variables considered in the selection. For example, the dimensionality of a model that considers only two variables, each including 10 categories, is 100. The addition of just one variable, also comprising 10 categories, boosts the dimensionality to 1000. The direct consequence is an average decrease in the number of points per cell, given the fixed size of the total number of examples in the database (in our case 307 638). Each point, therefore, includes ever fewer neighbours in each cell. A very high dimensionality, which can be achieved even by choosing a fairly small number of variables, would ultimately cause most of the cells to be empty, and in most cases any new point would have no neighbour. Such a situation may lead to overadjustment of the data and poor model performance owing to its excessive capacity. Moreover, it is conceivable, although this appears to be difficult to determine quantitatively, that the effective capacity of a model containing a large number of cells is much lower than the theoretical capacity. For example, if data distribution is

such that some combinations are excluded for physical reasons (for example, a particular ecological region never occurs at a given latitude, or a particular type of tree is rarely the most common in a given habitat), it is reasonable to believe that the model's real capacity would be considerably smaller than its theoretical capacity. In actual fact, the performance of a model, if measured appropriately through a series of tests, will be a sufficient basis for deciding whether to reject it or not.

Input variables

The choice of input variables for the models has a decisive impact, and this is true for both regression problems and classification. In the case of artificial neural networks (NN & NN-S), the variables were selected based on the following set of factors:

1. Latitude, ecological region, ecozone, habitat
2. Tree1, tree1 density, tree2, tree2 density, tree3, tree3 density
3. Shrub1, shrub1 density, shrub2, shrub2 density, shrub3, shrub3 density
4. Herb1, herb1 density, herb2, herb2 density, herb3, herb3 density
5. *Type of disturbance*

The first series above represents a subset of variables that can be obtained via satellite and hence may be called 'satellite' variables. They may be suitable for specific models in cases where this mode of data collection is employed. Series 2, 3 and 4 consist of so-called 'vegetation' variables: for a given survey they denote the most common tree species and the corresponding percentage of cover within a stand, the second most common species and so on, encompassing also shrubs and herbs. The fifth series consists of only one variable, namely the type of disturbance observed during the survey.

The non-parametric models (SM & SM-S) studied here consider only category-type variables; hence, the variables encoding density of trees, shrubs and herbaceous vegetation in a given region are not included. However, the latitude variable, although continuous, was recoded in 15 classes (of irregular extent according to sampling effort), and thus incorporated into the model. This was done because it seemed especially important for deriving species density predictions. By contrast, the variable encoding type of disturbance, although discrete in nature, was not included in the set.

Given how quickly this type of model can be developed, it is feasible to test a number of models that vary only in terms of their input variables. That is what we did: about 20 smoothers were developed at the same time (using a learning sub-set) and the best ones were selected and tested on the rest of the set (the test sub-set). This testing, which was repeated about 10 times, almost consistently produced the best performance for a given model compared with the other models.

One model (SM) accepts the following category variables as input: *species, latitude, habitat, tree1, shrub1, herbaceous plant1*

A satellite model (SM-S) was also tested. It considers only the variables whose values could be determined through satellite tracking: *species, latitude, ecological region, ecozone, habitat*

Estimation of models performance

The values of most of these 'predictor' variables were collected from the totality (1899) of ornithological surveys contained in our database. In each survey, an observer estimated the density of 162 bird species per 10 hectares. The resultant densities represent the set of

'predicted' variables. In all, the database therefore contains 307 638 examples (1899 x 162). One might be tempted to feed all of these examples into each model, since the expected performance of a model increases with the number of examples presented (or conversely the error rate decreases with this number). However, this would preclude any estimation of the expected performance, a measure that is nonetheless essential for assessing the absolute or relative quality of models. Consequently, it is necessary to divide the database and create one subset from which the model parameters can be estimated and another subset that will be used to test the models. In order to measure the expected risk associated with our models without devoting too much data to this end, we selected the cross validation method (see Vapnik 1998). In linear models, statistical theory provides several simple estimators (AIC, BIC, etc) of the generalization error under various sampling assumptions. These statistics can also be used as crude estimates of the generalization error in nonlinear models when you have a 'large' training set. However, they are usually less precise (and often optimistically biased) than other methods used in nonlinear modeling, such as to reserve part of the data as a 'test' set (split-sample validation), which must not be used in any way during training. Cross-validation is an improvement of split-sample validation that allows you to use all of the data for training. The disadvantage of cross-validation is that you have to retrain the net many times. We thus separated all of the survey data into five equal parts. For each of these portions, we developed a model with the complementary data (the remaining 4/5s) and tested the model with the current part (1/5). The final expected risk was then computed from the mean of the expected risks evaluated in each part. Furthermore, it may be useful to test a model using a particular subset of data, such as a subset representing a sample with unique characteristics in relation to the problem of interest. In the present study, we have explored both of these methods. With reference to the second method, our sample consisted of a set of 100 high-quality surveys carried out in 10 types of forest (10 examples of each) representative of southern Quebec, the region modeled.

A model can rarely be assessed on the basis of a single dimension. Often, it is advantageous to provide a number of distinct, but complementary, measures, in order to better qualify a given model. For example, classification models can be measured on the basis of their success rate (percentage of cases that are properly classified) or by a measure such as Jaccard's coefficient (Legendre and Legendre 1998), which excludes double absences from the calculation. This exclusion is justifiable: a double absence does not always have meaning other than the fact that it may be partly due (from the observer's standpoint) to an overly small sample size or improper sampling (a sample that records as absent certain species that are normally present) as well as to the natural tendency for a model based exclusively on data to answer zero, more often than not when the data presented show a predominance of zeros. These two measures may be useful in that they provide a different portrait of the same situation. Similarly, it may be interesting to break down the model errors with reference to various dimensions, such as the ecological region, habitat, type of species or individual survey, in order to determine the strengths and weaknesses of the models themselves. Finally, it is crucial to compare the results of the models with those obtained from so-called naïve models (naïve in the sense that their decisions are based on a minimum of information) and those obtained from 'human expert' models, in order to carefully identify the differences between them and arrive at an informed judgment regarding their individual merits.

Optimization criteria

We tried a number of different models adapted to the different questions being considered (prediction of density, of species presence-absence and prediction of the presence of many individuals, a medium number or few or no individuals of a given species):

- *A model of density.* In order to predict the density of a given bird species in a particular environment, we devised a model whose output consisted in a real number representing a density and where the optimization criterion was the most frequent. This entails minimizing the square deviation between the model output and the true density. The mean square deviation is the most widely used cost function for optimizing models like neural networks for various reasons: it can be derived (none of the other functions presented here can be), and it can be shown that minimizing such a function is equivalent to computing the expectation of obtaining the output, given the existence of a noisy environment where the noise has a Gaussian distribution. Departure from this assumption is, however, generally well handled by neural networks. The smoother makes no assumption about the parametric form of the target data. In that sense, we do not rely heavily on the Gaussian model. In the literature, this measure is often referred to as the mean square error. This criterion is called MSE for short.
- *Binary classification model.* With regard to the problem of binary classification (based on species presence or absence), we devised a model with an output by species: the assigned value was 0.6 when the species was present, and –0.6 when the species was absent. This model was subsequently trained using the MSE. A species is considered present when the model yields a positive value but absent otherwise.
- *A classification model with 4 classes.* In this case, we chose a model with four output units per species. Each example was recoded as follows: the desired outputs were all set at –0.6, except the unit corresponding to the desired class, whose value was set at 0.6. The model was then trained with the MSE. The predicted class for each species was then selected as the one for which the corresponding output unit had the largest value of the four possibilities.
- *A model optimizing Jaccard's coefficient.* As we will see later, the number of properly classified cases does not appear to be a good criterion of performance for some ecological problems. For example, if the problem involves predicting whether a given bird is found in a particular environment, it is highly likely that the answer will be no. In fact, most birds occur in a limited number of environments. In addition, when learning examples are collected in the field, there is always the possibility that the sampler may not detect a bird that is normally present. Jaccard's coefficient was proposed as a way of eliminating these two measurement biases. In the case of classification problems where one of the classes represents a species' absence from an environment, the evaluation of overall performance will not include all cases where the model predicted an absence when the expected answer was precisely that. This situation is generally referred to as the double-zero problem.
- *Comparison with naïve models and experts.* To be able to assess the performance of the models more effectively, we decided to compare their performance levels with the predictions obtained from other sources. Accordingly, we asked several bird experts to predict the relative abundance of the different bird species likely to nest in 13 broad habitat types in Quebec that can be identified from satellite images. These predictions were then checked against all of the surveys by selecting the answers for the habitat most representative of each survey (this approximation of experts' answers on the basis of the most representative habitat in each survey partly explains why the experts performed worse than the models).

We also proposed simple models that would only know the distribution of classes and the associated performance measurement:

- *A naïve model for the number of poorly classified cases.* Where only the distribution of examples is known, the best naïve model should always answer by giving the most likely class. Here, this is the class representing species absence.

- *A naïve model for Jaccard's coefficient.* Where only the distribution of samples is known and double-zeros do not count in Jaccard's coefficient, a naïve model designed to perform well on this measure should always answer by giving the second most likely class.
- *Expertise of Jean-Luc DesGranges (JLD) and André Desrochers (AD).*
- Jean-Luc DesGranges arranged for *the combined expertise of 11 experts* whose collective answers were considered a consensus (X11).

Results and Discussion

As mentioned earlier, the sample of data from which the avian density prediction models were developed is a set of 162 densities (each corresponding to a different bird species) collected in 1899 surveys. In all, the sample thus comprises 307 638 points. This set is characterized above all by a predominance of zeros: in 88.2% of cases, a given species was not observed in a given survey. The non-null densities thus make up 11.8% of the total; in other words, on average about 19 different species were observed in each survey. The mean density for a species, when computed solely among the species present, equals 3.9 pairs per 10 hectares, whereas the median, computed for this same set, is 1.9. This discrepancy can be explained by the presence of many extreme values, since some common species may have densities of several dozen breeding bird pairs per 10 hectares.

The three different problems discussed in this study relate to direct prediction of species density and the prediction of species abundance class on a scale that includes either four or two categories. The problem of class prediction on a scale of 1 to 4 requires identifying the four corresponding intervals. The first consists in all the densities smaller than 0.04 (in the data used, the smallest non-null observation was 0.04 birds per 10 hectares; hence, the decision was made to interpret any value below 0.04 as an absence). The three following ones are determined in a way that will result in about the same number of points: rare = 0.04 to 1.39, frequent = 1.40 to 2.69, common = 2.70 and over. The problem of predicting abundance class on a scale of 1 to 2 (in other words, the problem that involves predicting the presence or absence of a species) naturally uses the interval 1 from the last problem to define the 'absence' class and all the others to define the 'presence' class.

Measures of performance

The overall results for the experts, the models developed and the naïve model are presented in Table 1. The four models are presented in the following order: a neural network for which all the available variables served as input (the 23 variables mentioned in the methods), which is denoted as NN; a second neural network in which only the 'satellite' variables were used as input (latitude, ecological region, ecozone and habitat), which is denoted as NN-S; and two non-parametric models called 'smoothers' (SM and SM-S), which drew on all 23 variables and on the 4 satellite variables, respectively. Finally, a naïve model (NV) is also presented. We will see that the performance of the latter can shed light on the values of some of the measures used.

The performance levels of each of these experts or models were evaluated with reference to the prediction of species density and the prediction of species abundance class. The measure of performance for the *prediction of species density* is the absolute mean deviation between observed density and predicted density for each point in the set. The results show fairly similar results for the experts (0.58, 0.60 and 0.65); the performance of the first neural network (NN)

Table 1. Overall results.

		Sample (A) Cross-validation	Sample (B) Control subset
Number of census		1899	100
number of points		307638	16200
Class # 1	absent (<0.5 per 10 ha.)	88.17 %	82.75 %
Class # 2	rare (0.04–1.39 per 10 ha.)	3.78 %	4.02 %
Class # 3	frequent (1.40–2.69 per 10 ha.)	4.08 %	9.30 %
Class # 4	common (2.70 and over per 10 ha.)	3.97 %	3.93 %

		Sample (A)	Sample (B)
Absolute mean deviation between observed and predicted density	"Consensus" of 11 ornithologists (X11)	0.58	0.50
	André Desrochers (AD)	0.60	0.53
	Jean-Luc DesGranges (JLD)	0.65	0.58
	Neural network (NN)	0.65	0.74
	Satellite-based neural network (NN_S)	0.41	0.46
	Smoother (SM)	0.30	0.37
	Satellite-based smoother SM_S)	0.35	0.34
	Naive model (NV)	0.44	0.44

		% of properly classified cases		Jaccard coefficient	
		A	B	A	B
Success in predicting abundance of species (4 classes)	X11	48.80 %	49.20 %	6.60 %	8.90 %
	AD	61.79 %	60.73 %	7.81 %	10.67 %
	JLD	58.12 %	58.62 %	7.49 %	10.47 %
	NN	90.47 %	86.48 %	30.75 %	30.61 %
	NN_S	89.45 %	85.23 %	16.88 %	20.00 %
	SM	90.91 %	84.99 %	33.08 %	16.60 %
	SM_S	89.09 %	85.60 %	27.91 %	30.71 %
	NV	88.17 %	82.75 %	4.08 %	9.30 %
Success in predicting presence-absence of species (2 classes)	X11	42.40 %	46.30 %	16.10 %	23.00 %
	AD	67.13 %	68.72 %	20.70 %	28.84 %
	JLD	63.49 %	66.30 %	19.36 %	27.07 %
	NN	92.47 %	88.78 %	49.73 %	46.02 %
	NN_S	91.28 %	88.32 %	39.68 %	42.28 %
	SM	92.65 %	86.32 %	45.89 %	23.97 %
	SM_S	91.88 %	89.45 %	46.36 %	49.24 %
	NV	88.17 %	82.75 %	11.83 %	17.25 %

was comparable (0.64), whereas the three other models (NN-S, SM and SM-S) appeared to perform much better (0.41, 0.30 and 0.35). However, the naïve model's seemingly good performance (0.44) calls into question the relevance of the measure applied. The naïve model only has a minimum of information about the problem, or in this case, the predominance of zeros. The model using only this information would respond to each question with a consistent prediction of zero. This performance, which was better than that of the experts, is most certainly misleading. Clearly, a naïve model of this type would be unusable to all intents and purposes. This shows that the measure of density prediction is probably not perfect and must be combined with other measures in order to evaluate model quality more effectively.

The same principle applies to a simple measure employed for the *prediction of the abundance class*, namely the success rate (percentage of properly classified cases). The performance of the neural network and smoother models are comparable and in the order of 90%, versus 42%–67% for the experts. However, since the naïve model (whose sole response in this case is class 1: absent) gives a better performance (88%) than the experts, whether the problem has 4 classes or 2, we most conclude that success rate is not a perfect measure either. It must be used in combination with other measures such as the Jaccard's coefficient. When performance is evaluated by such a measure, the neuronal and smoother models come out ahead of the experts in both classification problems. In the problem with 4 classes, the experts obtained a result of 6%–8%, whereas the models' performance was about 30% (except for the satellite neural network (NN-S), which performed below 17%). In the 2-class problem, all the performances were higher (since this problem was easier than the first one) although this did not change the ranking established before. In general, the models appeared to perform better than the experts, and the satellite models appeared to underperform the non-satellite ones (except for SM-S, which outperformed SM in the 2-class problem). With regard to the success rates obtained for Jaccard's coefficient, the naïve model ranks last this time (4% and 12% for the problems with 4 and 2 classes, respectively).

The performance levels were likewise examined according to the different bird species (the table is too large to present here). The presence of the 162 bird species is divided non-uniformly among the surveys. Some birds are very rare (present in less than 1% of surveys), whereas others are present in more than 60% of surveys. Overall, it can be seen that the greater a species' occurrence, the better the performance of the models, the experts and the naïve model. In addition, the models generally perform better than the experts, regardless of the species' occurrence rate (except in certain cases where the rates are low). Finally, the experts generally outperform the naïve model.

For the problem consisting in predicting density, the performance of the experts and the models was (fairly) similar (except for two bad performances by the neural network relative to the Common Grackle (*Quiscalus quiscula*) and the Red-winged Blackbird (*Agelaïus phoeniceus*), two semi-colonial species; see Figure 3). As a rule, the birds for which the models and experts answered less effectively are common bird species. For the two problems that involved measuring Jaccard's coefficient (with 4 and 2 classes), both the experts and the models had a success rate of nil for the worst species. In addition, the experts and the models performed badly for nearly all the same species. In the table of bird species (not presented here), if we look at the occurrence rate for the species for which all models and experts gave incorrect answers, we see that the species are very rare ones (occurrence rate below than 1%). Hence, it is interesting to note that the experts and the models made the same types of error: (1) when the species is rare, the Jaccard's coefficient performance is poor; (2) when the species is frequent, the species density prediction is poor.

We should mention that the portrait provided above is very nearly the same for the subset of 100 census considered especially representative of Quebec forests (Table 1), suggesting that these 100 surveys, although few in number, are quite representative of the totality of surveys. Hence, the overall performances of all four models appear to be remarkable as illustrated in the following two figures.

For each model, the first graph (Figure 2) provides a series of curves representing the mean density error by percentile (thus, the last percentile shows the largest mean error made by each model for the most difficult examples). As can be seen, all the models start to make errors later than all of the experts (nearly 20 percentiles later), although in the end most of the experts and models make the same kinds of major error. It should be noted, however, that the neural network (NN), which begins making errors 'late', ends up making the biggest errors.

Figure 3 compares the predictions of the best expert (AD), and those of two models (SM-S and NN) with the actual observations, for each species. The species are listed in increasing

order of mean density per 10 hectares. Here again, it is clear that the models' answers more closely approximate the observed situation compared with the expert's predictions. It can also be seen that, although the models often give similar answers, there are also discrepancies, and these could be exploited by finding ways to combine the responses.

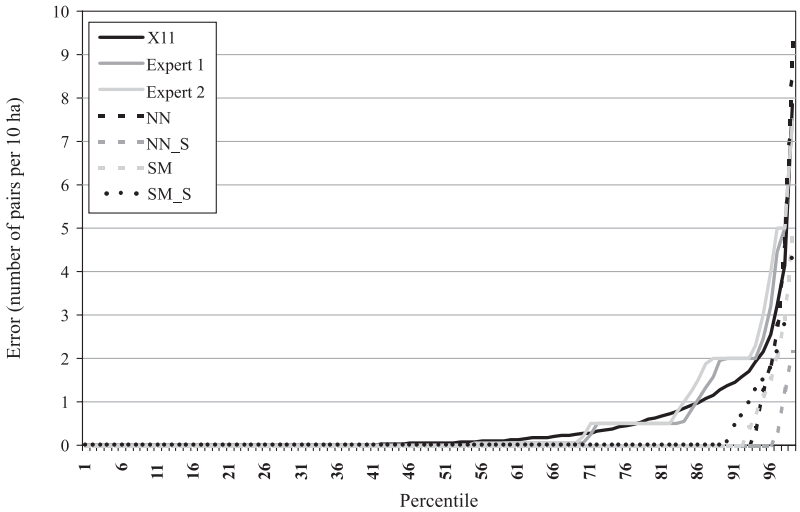
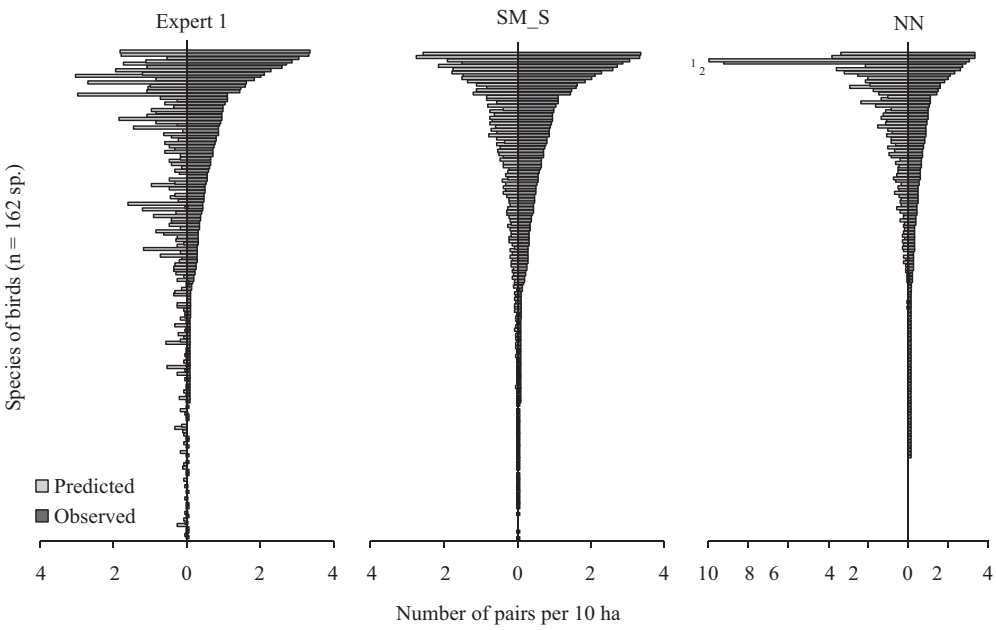


Figure 2. Evolution of the absolute error on predicted density (excluding the last percentile; n = 1899 counts).



Species: **1** *Agelaius phoeniceus*; **2** *Quiscalus quiscula*

Figure 3. Comparison of observed densities with those predicted in three different ways (n = 1899 counts).

Table 2. Prediction of the presence-absence of 162 species (summary results from 1899 counts).

X11

	Actual observations		
Prediction	**absence**	**presence**	
absence	31.32 %	0.80 %	32.12 %
presence	56.85 %	11.03 %	67.88 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	42.35 %
		Jaccard	16.06 %
		absence	35.53 %
		presence	93.23 %

AD

	Actual observations		
Prediction	**absence**	**presence**	
absence	58.55 %	3.25 %	61.80 %
presence	29.62 %	8.58 %	38.20 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	67.13 %
		Jaccard	20.70 %
		absence	66.41 %
		presence	72.53 %

JLD

	Actual observations		
Prediction	**absence**	**presence**	
absence	54.73 %	3.07 %	57.80 %
presence	33.44 %	8.76 %	42.20 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	63.49 %
		Jaccard	19.36 %
		absence	62.08 %
		presence	74.05 %

NV

	Actual observations		
Prediction	**absence**	**presence**	
absence	0.00 %	0.00 %	0.00 %
presence	88.17 %	11.83 %	100.00 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	11.83 %
		Jaccard	11.83 %
		absence	0.00 %
		presence	100.00 %

NN

	Actual observations		
Prediction	**absence**	**presence**	
absence	85.02 %	4.38 %	89.40 %
presence	3.15 %	7.45 %	10.60 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	92.47 %
		Jaccard	49.73 %
		absence	96.43 %
		presence	62.98 %

NN_S

	Actual observations		
Prediction	**absence**	**presence**	
absence	85.54 %	6.09 %	91.63 %
presence	2.63 %	5.74 %	8.37 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	91.28 %
		Jaccard	39.70 %
		absence	97.02 %
		presence	48.52 %

SM

	Actual observations		
Prediction	**absence**	**presence**	
absence	86.42 %	5.59 %	92.01 %
presence	1.75 %	6.24 %	7.99 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	92.66 %
		Jaccard	45.95 %
		absence	98.02 %
		presence	52.75 %

SM_S

	Actual observations		
Prediction	**absence**	**presence**	
absence	84.86 %	4.81 %	89.67 %
presence	3.31 %	7.02 %	10.33 %
	88.17 %	11.83 %	**100.00 %**
	Success	*standard*	91.88 %
		Jaccard	46.37 %
		absence	96.25 %
		presence	59.34 %

Types of errors

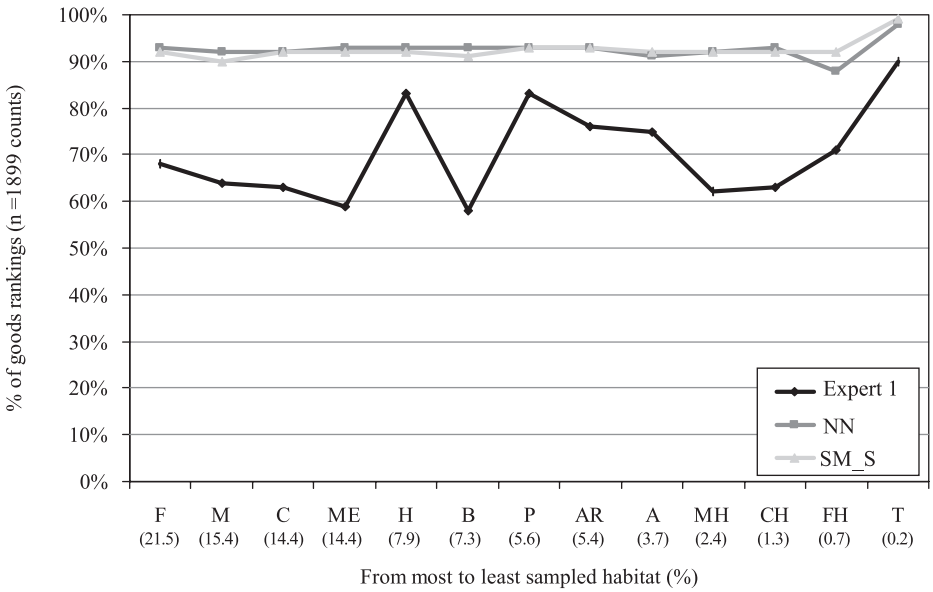
The contingency tables presented in Table 2 provide an idea of the value of the results obtained for the 2-class problem since the errors are broken down into two possible types: 'errors of omission' (reporting an observed species as absent); and 'errors of commission' (reporting as present a species that was not observed). It is clear from these tables that the primary cause of the experts' poorer performance compared with that of the models, as measured by Jaccard's coefficient, is their tendency to overestimate the species' occurrence.

Thus, although the models and experts should theoretically have predicted the absence of 88% of the species, AD reported only 62% as absent, JLD 58% and X11 32%. All the species that were incorrectly identified by the later as being present (errors of commission) caused a noticeable decrease in the value of Jaccard's coefficient for the experts. Conversely, the models much more frequently predicted the absence of species (between 89% and 92% of cases about), a situation that reflects the predominance of zeros in the data set. With these models, it is errors of omission that reduce performance the most. In summary, the experts make mostly errors of commission, whereas the models make errors of omission. The experts' errors of commission exceed the models' errors of omission, and this largely explains their poorer performance with respect to Jaccard's coefficient. It should be noted that the species that were incorrectly reported as present may possibly be encountered in this type of habitat, but are not always detected, given the limitations of census methods. For example, the small surface area of many of the sampled habitats would have reduced the chances of encountering the rarest species there.

Cross-sectional results

The 'cross-sectional' results based on several dimensions (such as results per ecological region, per habitat, or per forest type) were also examined. The tables are too extensive to be presented in this paper. With respect to most of the results, the models generally outperformed the experts and no appreciable difference is noted between ecological regions, habitats or forest types in terms of the models' or experts' performance levels, and this applies to density prediction error, success rates and Jaccard's coefficient values. By way of example, Figure 4 compares two models (NN and SM-S) and the best expert in terms of the problem of predicting the presence-absence of bird species broken down by habitat.

The surveys are separated into 13 distinct habitats in a non-uniform fashion. For example, habitat F represents more than 21% of the totality of surveys, while habitat T includes only 3 surveys, or 0.16% of the totality. The McNemar test (Scherrer 1984) was used to compare the expert's sample with the NN sample and with the SM-S sample. This test applies only to the qualitative binary variables comprising two categories, i.e. 'success' and 'failure'. It seeks to determine whether the success rate is identical in the two samples. This was done initially for all observations and then separately for each habitat. Each test showed that the discrepancy between one or more of the models and the expert was significant, with a significance level of 1%. In other words, the models' success rate was significantly greater than that of the expert. Even though the models' performance is good and vary little from one habitat to another, it is important to base our value judgment on habitats containing a large number of bird counts, namely habitats F, M, C and ME which cover more than 65% of the surveys. Moreover, as ecological regions FMB (Shield mixed forest), HTA (Atlantic highlands) and PFM (Mixed forest plains) alone cover more than 86% of the surveys, it is in those ecological regions that individual performance levels will have the greatest impact on overall performance.



Habitats: F = Dry deciduous forest; **M** = Dry mixed forest; **C** = Dry coniferous forest; **ME** = Disturbed mixed forest; **H** = Wetlands; **B** = Isolated woodlands and agro-ecosystems; **P** = Prairies; **AR** = Successional shrubland; **A** = Climax shrubland; **MH** = Wet mixed forest; **CH** = Wet coniferous forest; **FH** = Wet deciduous forest; **T** = Tundra.

Figure 4. Evolution of the good rankings for the prediction of presence-absence (habitat situation).

Figures 5 and 6 show the overall results of the four models for the mixed forest. We used linear regression to compare the predictions derived by the four models with the observations (excluding double zeros) made in mixed forests (n = 610 surveys).

In the case of presence-absence predictions (Figure 5), all the models showed remarkable performances. The r^2 performance levels were all very high, highlighting the fact that the fit of the equations and the straight lines nearly all follow the quadrant bisector. The smoother (SM) is the only model that provides occurrence values underestimating the presence of species identified during surveys. With respect to density prediction (Figure 6), the performance levels are a little more variable.

The satellite neural network (NN-S) performed at a mediocre level, while the smoothers (SM and SM-S) produced good r^2s, but underestimated to an appreciable extent the density actually measured in the surveys. Although the r^2s are a little smaller, the density predictions obtained with the neural network (NN) are quite acceptable in the case of recently disturbed mixed forests, but represent somewhat of an underestimation for more intact mixed forests.

Another analysis relates to the same type of result as Table 1, albeit with a breakdown by survey (n = 1899). By way of example, Figure 7 shows the results from three particular surveys. It shows the similarity between the actual survey data and those predicted by the smoother (SM) for three very different types of forest: a sugar maple-yellow birch stand, a balsam fir-white birch stand, and a tamarack swamp.

The model's capacity to accurately predict the presence and abundance of the different species (this assemblage differs greatly from one forest to the next) that have nested in each of the stands is quite remarkable. In the study by Holmes et al. (1986), a series of breeding bird surveys were conducted over 16 consecutive years in a single, slightly disturbed northern

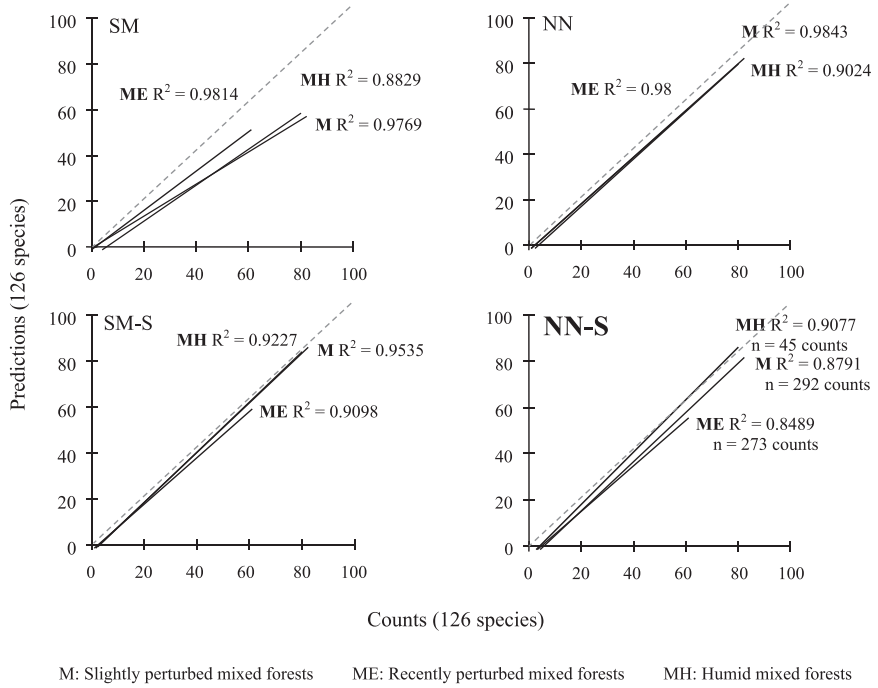


Figure 5. Performances of the models in predicting the presence-absence (%) of bird species in three types of mixed forest.

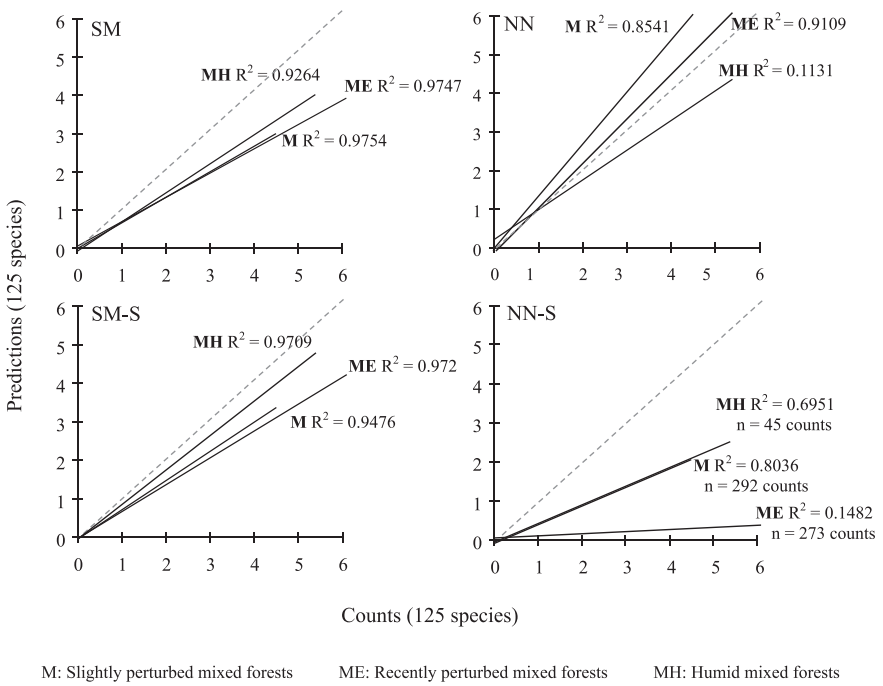
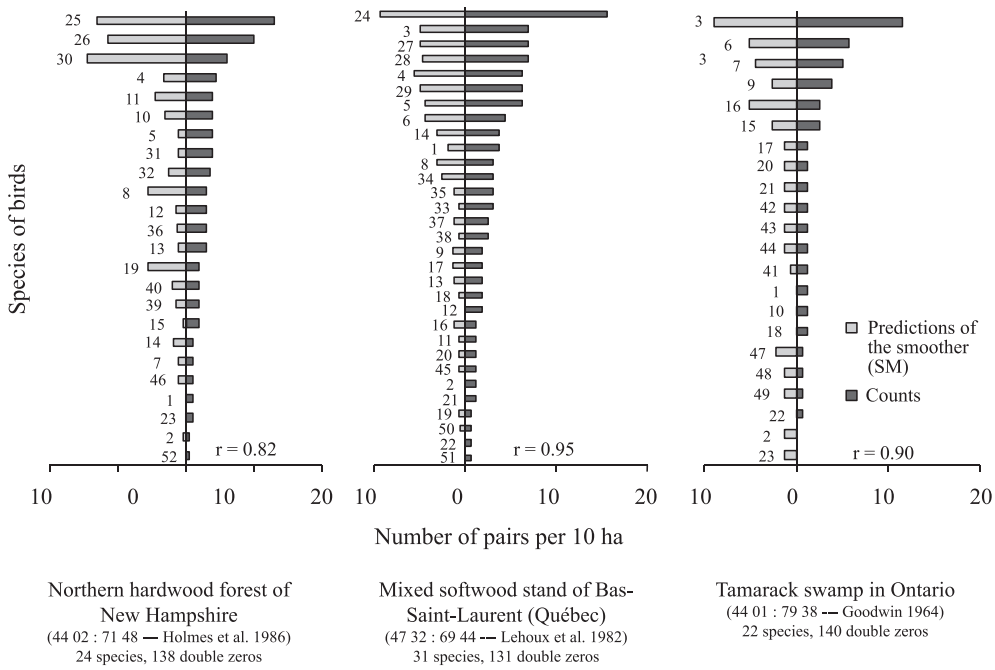


Figure 6. Performances of the models in predicting the mean abundance of bird species in three types of mixed forest.



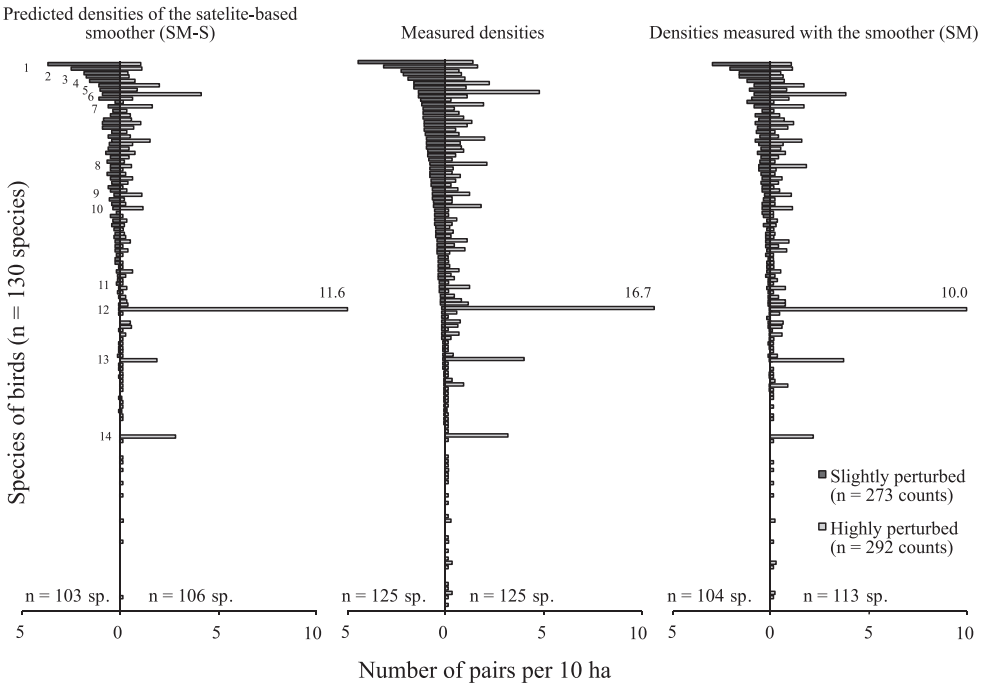
Species present 3 times: 1 *Carpodacus purpureus*; **2** *Troglodytes troglodytes.* **Species present 2 times**: **3** *Zonotrichia albicolis*; **4** *Catharus ustulatus*; **5** *Junco hyemalis*; **6** *Vermifora ruficapilla*: **7** *Catharus fuscescens*; **8** *Seiurus aurocapillus*; **9** *Turdus migratorius*; **10** *Pheucticus ludovicianus*; **11** *Dendroica virens*; **12** *Sphyrapicus varius*; **13** *Catharus guttatus*; **14** *Dendroica fusca*; **15** *Parus atricapillus*; **16** *Geothlypis tricas*; **17** *Wilsonia canadensis*; **18** *Sitta canadensis*; **19** *Dendroica caerulescens*; **20** *Seiurus noveboracensis*; **21** *Bonasa umbellus*; **22** *Colaptes auratus*; **23** *Certhia americana*. **Species present once**: **24** *Vermivora peregrina*; **25** *Empidonax minimus*; **26** *Vireo olivaceus*; **27** *Dendroica castanea*; **28** *Dendroica tigrina*; **29** *Dendroica magnolia*; **30** *Setophaga ruticilla*; **31** *Sitta carolinensis*; **32** *Hylocichla mustelina*, **33** *Regulus calendula*; **34** *Empidonax flaviventris*; **35** *Dendroica coronata*; **36** *Picoides pubescens*; **37** *Parus hudsonicus*; **38** *Vireo solitarius*; **39** *Vireo philadelphicus*; **40** *Piranga olivacea*; **41** *Mniotilta varia*; **42** *Molothrus ater*; **43** *Cyanocitta cristata*, **44** *Myiarchus crinitus*; **45** *Perisoreus canadensis*; **46** *Picoides villosus*; **47** *Zenaida macroura*; **48** *Melospiza georgiana*; **49** *Empidonax traillii*; **50** *Spizella passerina*; **51** *Gallinago gallinago*; **52** *Contopus virens.*

Figure 7. Comparison of observed densities with those predicted (by SM) for three counts conducted in three major forest types.

hardwood forest in the Appalachians. Lehoux et al. (1982) used three survey techniques, including netting of territorial birds, to assess the effects of a spruce budworm (*Choristoneura fumiferana*) infestation on the avifauna of a balsam fir-white birch stand in Quebec. Goodwin (1964) is an ornithologist who conducted several of the Ontario surveys contained in the BBC database.

In view of the quality of the predictions made by the smoothers, it might be useful to use such predictions, together with the survey data contained in our database, to evaluate the effects of forest disturbances on the composition of bird communities in the commercial forests of northeastern North America (Figure 8).

Although the predictions from these models provide a fairly reliable picture of the densities measured during surveys (565 in all), the situation is altogether different for comparisons of the two types of habitat. The most disturbed mixed forests (n = 273 surveys) usually are home to more species than mixed forests that are relatively undisturbed (n = 292 surveys). Those forests also contain a larger number of species that prefer forest clearings, such as the Common Grackle (*Quiscalus quiscula*), the American Robin (*Turdus migratorius*), the Mourning Dove (*Zenaida macroura*), the European Starling (*Sturnus vulgaris*) and the



Species more common in the slightly perturbed forest: **1** *Seiurus aurocapillus*; **2** *Vireo olivaceus*; **3** *Dendroica fusca*; **4** *Dendroica virens*. **Species more common in the highly perturbed forest**: **5** *Turdus migratorus*; **6** *Dendroica pensylvanica*; **7** *Geothlypis trichas*; **8** *Melospiza melodia*; **9** *Dendroica castanea*; **10** *Spizella passerina*; **11** *Dumetella carolinensis*; **12** *Quiscalus quiscula*; **13** *Sturnus vulgaris*; **14** *Zenaida macroura.*

Figure 8. Comparison of observed densities with those predicted by the bin smoother for birds of the mixed-wood forest according to level of perturbation.

Chesnut-sided Warbler (*Dendroica pensylvanica*). Only a few species are more abundant in mixed forests that are virtually intact. They include the Ovenbird (*Seiurus aurocapillus*), the Red-eyed Vireo (*Vireo olivaceus*), the Blackburnian Warbler (*Dendroica fusca*) and the Black-throated Green Warbler (*Dendroica virens*), the most common species in the Appalachian mixed forest.

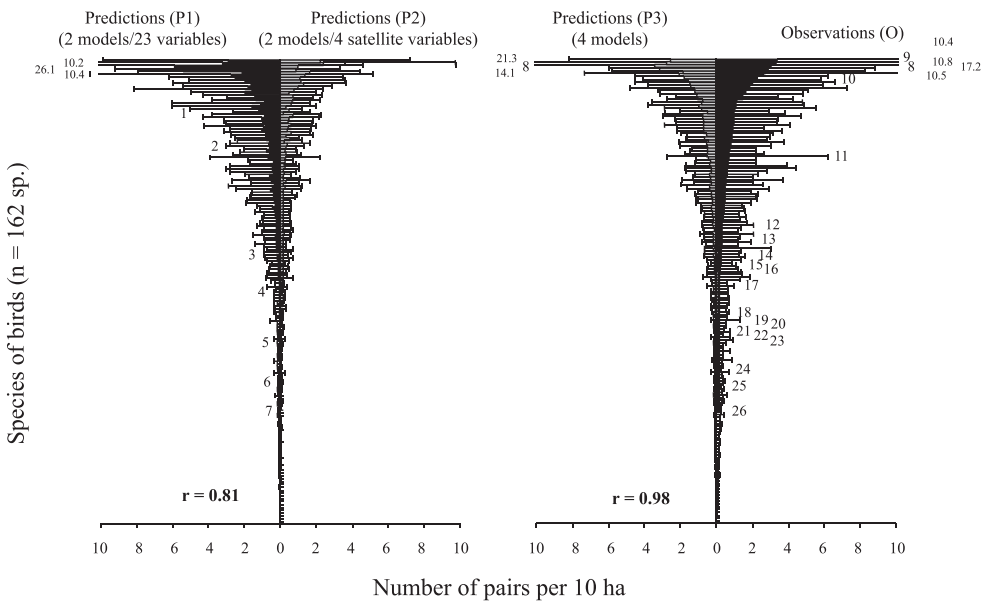
Conclusion

This study highlighted the difficulty of designing an effective measure for describing the quality of the models developed. Some measures such as the success rate or the absolute value of the density error appear to be imperfect, because it is easy to develop a simple model that performs well according to these measures, but is unacceptable in relation to the experts. Jaccard's coefficient seems to be a better measure, but it still seems to be less than perfect. A simple model that consistently answers *present* provides a reasonable performance, although it performs worse than the experts. New measures should, therefore, be envisaged, with one being a measure that imposes a considerable penalty on a *constant* model. One possible solution might be to develop a model that estimates not only the expected mean for every bird species in each survey, but also the standard deviation of the values. Thus, a model that

always answers the same thing would have a standard deviation of 0 whereas the standard deviation for expected answers would be much higher. Another solution would be to come up with a measure that is midway between the success rate and Jaccard's coefficient. It is clear that a great deal of work remains to be done to devise an acceptable measure. This work could be undertaken in a future study.

Furthermore, even if the models turn out to be less effective than they appear to be based on the measures developed in this study (or not as good as the experts), we think that if experts find their performance levels acceptable, they may at least be useful from the standpoint of economy (computer time costs less than an expert's time). It should be noted that, judging from the measures used in this study, the *satellite* models appear to perform satisfactorily compared with the experts. In addition, the satellite smoother, SM-S, has fewer parameters than the SM smoother (more than 20 fewer in fact); however, this does not affect its performances greatly.

Although the proposed models appear to outperform the experts on most problems, none of the models appear to consistently perform better than the others, regardless of the problem being processed. Although we can choose the best performing model according to this study, this choice would bias the expected performance levels in new surveys. A better solution, which was put forward in the literature a few years ago (Perrone and Cooper 1993; Bishop 1995), consists of combing the approaches of the different models (Figure 9). Several types of combinations were recently put forward and most of them tend to increase the robustness of the models by reducing their variance. It would be useful to continue this research by focusing on the different types of combinations of models that could be applied to the problems defined in the present study.



Species that differ significantly between P1 and P2: **1** *Sturnus vulgaris*; **2** *Carduelis tristis*; **3** *Passerina cyanea*; **4** *Archilochus colibris*; **5** *Dryocopus pileatus*; **6** *Vermivora chrysoptera*; **7** *Caprimulgus vociferus*. **Species that differ significantly between P1 and O and P3 and O**: **8** *Agelaius phoeniceus.* **Species that differ significantly between P1 and 0**: **9** *Vireo olivaceus*; **10** *Zonotrichia albicollis*; **11** *Oporornis philadelphia*; **12** *Passerculus sandwichensis*; **13** *Vireo solitarus*; **14** *Seiurus noveboracensis*; **15** *Empidonax flaviventris*; **16** *Dendroica tigrina*; **17** *Parus hudsonicus*; **18** *Carduelis pinus*; **19** *Coccothraustes vespertinus*; **20** *Loxia leucoptera*; **21** *Gallinago gallinago*; **22** *Passerella iliaca*; **23** *Coccyzus erythropthalmus*; **24** *Buteo platypterus*; **25** *Corvus corax*; **26** *Picoides arcticus*.

Figure 9. Comparison between observed bird densities and mean densities derived from various model combinations (n = 1899 counts).

Meanwhile, although the present versions of the species prediction models require adjustments in terms of data presentation and probably neural network configuration, the results obtained so far already show considerable potential in terms of rapid and effective assessment of avian biodiversity in the forest environment. The models that have been developed draw on known data; they are able to perfect their learning as new knowledge is acquired about relationships between bird species and their nesting habitats. When used in conjunction with satellite imagery for a given region, the predictions obtained from such models could be an invaluable asset for integrated management of forested areas.

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We are grateful to Pierre Belleau and Richard Savard of the Lower St. Lawrence Model Forest Inc. and Ian Thompson of the Canadian Forest Service, who secured funding for this project under government initiatives for the development of computerized decision support systems for sustainable forest management. As well, we thank André Bélanger and Richard Poulin, who structured the databases for the project, and Yves Grégoire who conducted the statistical analyses used in validating the models, and Jean-François Isabelle who provided advice on adaptive models.

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Is Imitating Nature the Solution for Sustainable Boreal Forest (Black Spruce) Management in Eastern Canada?

Réjean Gagnon

Université du Québec à Chicoutimi
Chicoutimi, Québec, Canada

Abstract

In the Canadian Northeast, black spruce (*Picea mariana*) is the dominant species of tree in the boreal zone, where it forms large and often monospecific natural virgin stands. This spruce is present only in North America. The integration of fires in the functioning of these boreal forest ecosystems forced ecologists to revise the relevance of the application of the concepts of succession and climax as natural processes in these forests. Recent studies, based on the mechanisms of regeneration of the black spruce after fire, led to the development of a new natural dynamic model that is not based on the traditional concepts of succession and climax. This model is based upon the closed type (cyclic) and open type processes. As the closed type processes allow a return of the forest in a natural way, one can presume that the restarting of these processes during forestry management should favor the establishment of forests similar to those that were present originally. Imitating nature within this framework should allow sustainable forest management. Open process, as opposed to closed process, does not allow the return to the starting point. Instead, they conduct to the decline of the black spruce forest. Within this framework, imitating nature does not allow for sustainable forest management. Since this open process has been going on for a long time, a great number of black spruce forests have already naturally disappeared in the boreal zone. Therefore, imitating nature does not always allow sustainable forest management.

Keywords: black spruce, Picea mariana, open type processes, closed type processes

Introduction

The imitation of nature in forest management is not a new idea. Mr. Bernard Lorentz, the founder of ENGREF (École nationale du génie rural des eaux et des forêts, France), had

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promoted this idea in his teaching as early as the beginning of the nineteenth century. This idea, to imitate nature, has always been present in the mind of responsible foresters. It is a strong driving force in forest management.

The use of nature as a model to manage forest ecosystems appears quite thoughtful and safe. However, in order to do that, we have to define and to describe those natural models or processes and, for that to be done, we need to have access to large and untouched natural forest ecosystems. Huge virgin coniferous forests still exist in northeastern Canada. About 20 years ago, we started our studies on the evolution and the dynamics of the northeastern Canadian boreal forest (Gagnon et al. 1999).

Black Spruce Forest

The boreal forest in the eastern portion of North America is massively dominated by black spruce (*Picea mariana*, (Mill.) B.S.P.). Black spruce is only found naturally in North America. The largest black spruce forests are located in the eastern section of Canada, in the provinces of Quebec, Ontario and Newfoundland. The world's largest black spruce forests grow in Quebec, on public land.

Since the 1970s, several studies have clearly shown that fire is a natural and recurrent ecological factor in the boreal forest (Heinselman 1973; Swain 1973; Van Wagner 1978). If we include fire as an ecological factor in the normal operating cycle of boreal ecosystems, we are forced to question the relevance of applying the notions of succession and climax as fundamental evolutionary processes in these ecosystems. Given the frequent occurrence of fire and the fact that the boreal forest species have adapted well to disturbance by fire, many authors have pointed out the absence of true succession and climax in the boreal forest (Dix and Swan 1971; Methven et al. 1975; Viereck 1981, in Heinselman 1981; Heinselman 1981; Cogbill 1985; Gagnon 1988; 1989). Most of the species on a site are reestablished immediately after a fire, although their proportions can vary and there is no species replacement (Methven et al. 1975; Heinselman 1981; Viereck 1981 in Heinselman 1981). Heinselman (1981) pointed out that there is no one-way development of vegetation in the northern boreal forest, and that there are no so-called climax communities.

New Model of Natural Dynamics for Black Spruce Forests

Once it was understood that the notions of succession and climax did not apply to the black spruce forest domain, it became necessary to find an alternative explanation for the natural postfire dynamics of pure black spruce stands. Therefore, we have developed a new model of natural dynamics for black spruce stands (Gagnon et al. 1999). For the most part, the model is based on the natural regeneration mechanisms of the tree species present in the boreal forest. It does not use the concepts of succession and climax, but refers instead to the closed or cyclic processes identified by researchers studying boreal forest ecosystems where fire is a recurring phenomenon. The model also introduces a feature that is innovative in the boreal forest context: the notion of open processes which, depending on circumstances, can naturally and irreversibly convert a black spruce dominated forest ecosystem into another type of ecosystem.

The natural dynamics of black spruce stands are mainly governed by ecological processes of the closed (cyclic) and open types. The closed process can be summarized as follows: after a fire, a pure black spruce stand will regenerate into a similar stand without succession,

providing that it was originally composed of mature trees with viable seeds, and providing that the germination and seedling survival conditions are adequate. Closed type processes are the most common in the black spruce forest.

On the other hand, if the stand had not reached maturity (few seeds) before the fire, if the seeds are infested with parasites or if the germination and seedling survival conditions are inadequate, the stand type will change after a fire. It is in such circumstances that the open type process occurs: black spruce regeneration is weak and the species regresses. Regression may occur in two ways, depending on circumstances. The black spruce will then be replaced either by companion species or by open spruce woodland.

Stand Opening

Once the open process is underway in a sector with no black spruce companion species, it leads to the formation of open forests such as forest woodlands (heath) and lichen-spruce woodlands. Subsequent fires will maintain these open formations, and the density of the black spruce population will decline steadily from one fire to the next. A study currently underway near the Mistassibi River in a lichen-spruce woodland, located at about 50ºN and within the spruce feathermoss forest zone with three generations of postfire black spruce trees, has revealed a significant decline in density after each generation, as well as a gradual opening up of the stand (Côté, personal communication). The only significant regeneration process on these open sites is layering, but this method does not appear to help close up the canopy (Riverin and Gagnon 1996). Once the process of opening has begun, it is unlikely that the black spruce will return or that the stand will close up again (Riverin and Gagnon 1996).

The explanation for this phenomenon lies in the black spruce's postfire regeneration dynamics. It is now known that the postfire establishment of black spruce seedlings occurs quickly. St-Pierre et al. (1992) showed that more than 95% of the seedlings inventoried five years after a fire had become established during the three years following the fire. Maximum establishment occurs in the first years and seedling establishment declines quickly after that. Three factors are especially important in postfire regeneration establishment: (1) the availability of viable seeds; (2) the condition of the seedbed; and (3) the conditions required for the survival of the seedlings. These factors may help explain the short postfire establishment period for the black spruce. It is generally agreed that: viability of black spruce seeds in the cones declines gradually after a fire (Wilton 1963; Zasada et al. 1979); seed dispersal declines over time (Wilton 1963); seeds cannot survive more than a year on the ground (Frank and Safford 1968; Thomas and Wein 1985); and finally, that germination conditions become less favorable over time. Favorable seedbeds are becoming rarer, even though it is known that the quality of the seedbed is important for seed germination and seedling survival (Filion and Morin 1996). Over time, competing vegetation also takes up more space (Richardson 1972). Therefore, if regeneration does not occur during the short establishment period, it is highly unlikely that the black spruce will be able to naturally recolonize the burnt area (Gagnon 1988). This will result in an opening up of the stand.

The process of stand opening is not a new phenomenon. It has existed for a very long time in the forest-tundra all around the North Pole (Hustich 1966). A process of deforestation by fire has been observed in the north of Quebec for the past 3000 years, producing the forest tundra (Payette and Gagnon 1985). Changes such as this, at the landscape level, are still underway even today, especially at the boreal-subarctic interface.

It is rare for two fires to occur within a short period of time, but this is nevertheless an effective deforestation process in the northern boreal forest (Sirois 1988; Sirois and Payette

1991). The recurrence of two fires within a period of approximately 50 years or less leads to the elimination or radical reduction of black spruce trees on the damaged sites (Sirois 1988).

Gagnon and Payette (1985) said that black spruce formations at the timberline regressed following the occurrence of fires during periods when sexual propagation was inhibited. In current conditions, tundroid land is tending to expand post-fire, at the expense of conifer formations (Gagnon and Payette 1985). A number of authors working at the altitudinal (Billings 1969; Viereck 1973) or latitudinal timberline (Bryson et al. 1965; Rowe and Scotter 1973; Wein and Weber 1974; Nichols 1975; Black and Bliss 1978; Payette 1980), highlighted the phenomenon of tundra expansion following the failure of some tree species to regenerate postfire. The natural deforestation process that has been underway in the subarctic zone for several thousands of years involves fire-climate interactions (Payette and Gagnon 1985). These ecological factors contribute to the progressive decline of the forest canopy, culminating in local extinction of certain tree species (Payette and Gagnon 1985). As a result, some portions of the forest tundra, located at the tree line, no longer contain black spruce trees, even though the species is known to have been present there in the past. The macrofossils and subfossils found in the area provide evidence that the species used to be present before it was progressively eliminated by fire (Gagnon and Payette 1985). A postfire decline in black spruce regeneration, compared with original population densities, has also been observed (Sirois 1988; Sirois and Payette 1991). Subarctic deforestation is more often due to recurrent reductions in tree population densities following several fires than to a complete absence of regeneration after a single fire (Sirois 1988; Sirois and Payette 1991). Fires can also cause jack pine (*Pinus banksiana*) populations to expand at the expense of the black spruce (Desponts and Payette 1992; 1993; Lavoie 1994; Lavoie and Sirois 1998).

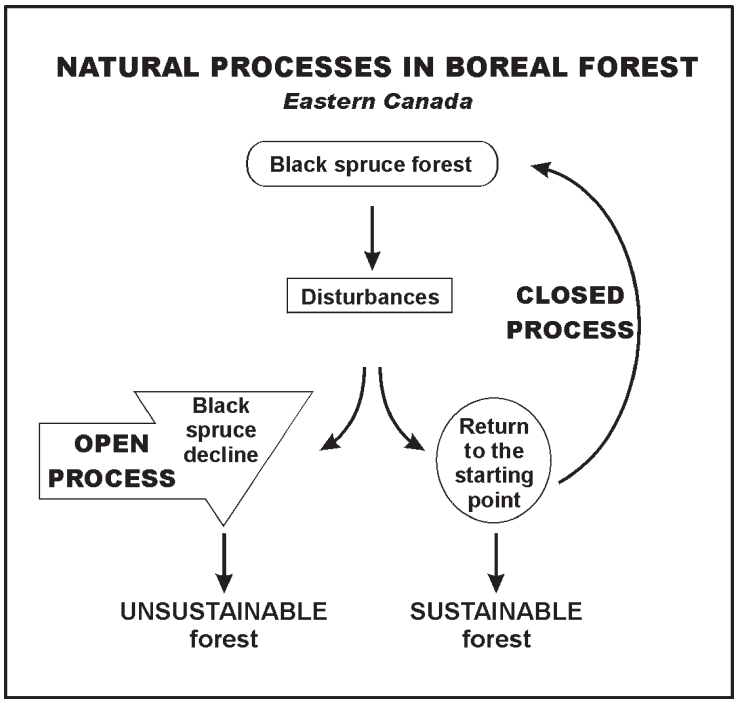

Figure 1. Schematic action of closed and open processes on sustainable black spruce forest management.

Clearly, fires have been the main instrument of subarctic deforestation in the Quebec-Labrador region (Sirois 1996). Studies of charred conifer remains suggest that fires have been active in the region since 6000 BC, if not earlier (Desponts and Payette 1993). The black spruce is, therefore, naturally declining in the subarctic zone. The new model of natural evolution for black spruce forests suggests that this phenomenon is not confined to the subarctic zone, but may also be occurring in the continuous spruce feathermoss forest where, for example, immature black spruce forests do not regenerate post-fire due to a lack of seeds.

Conclusion

Is imitating nature the solution to sustainable forest management? The answer is 'Yes', if cyclic processes are underway (Figure 1), and it is 'No', if open processes are started up.

Being aware of the natural action of this open process, we, as humankind, have to take care not to facilitate its progression. We have to fight against it. We are justified to restore the forest, like the Scandinavians have done since the beginning of the last century (Hustich 1966) and consequently to maintain the biodiversity associated with closed black spruce forest. Nature does not always go for sustainable forests. The imitation of nature is not a panacea. Sometimes, humans might have to give a helping hand to nature. In order to manage these forests in a sustainable way, we must learn as much as we can about how they function. Knowledge is a vital component in the development of a management method that takes the natural dynamics of the black spruce forests (Gagnon and Morin 2001) into account.

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Landscape Visualisation Software as a Forest Management Decision Support System

Daniel Auclair[1], Jean-François Barczi[1], Frédéric Borne[1], Michel Étienne[2]

[1]CIRAD & INRA, UMR Botanique et Bioinformatique
de l'Architecture des Plantes, Montpellier, France
[2]INRA, UR Écodéveloppement; Avignon, France

Abstract

Sustainable management should take into account the visual impact on the landscape, as it can offer many opportunities for enhancing the aesthetic value of forests or woodlands. The effect of management options is, however, not easy to convey to decision makers and to the general public. Landscape visualisation software can help bring together the elements of a large-scale landscape project. A case study showing the effect of silvopastoral management on environmental changes in a forested area is presented. Various management options have been tested, providing a basis for discussion between partners concerning spatial organisation, such as the layout of forest and agricultural plots.

Keywords: plant architectural model, computer mock-up, computer model, agroforestry, landscape

Introduction

Trees are generally considered as important features of the landscape. Most people consider rural landscapes to be timeless, and resistance to any change is often very great. Forest management can arouse public antipathy, and in areas of great natural beauty can lead to outspoken criticism (Savill et al. 1997). Conversely, depending on how forest management is carried out, there are many opportunities for enhancing the landscape value of forests or woodlands (Insley 1988; Hibberd 1988). Étienne and Rapey (1999) analysed the objectives of farmers interested in the development of agroforestry projects. Their conclusions revealed that many non-market factors influence farmers' decisions. In particular, it was noticed that all the interviewed farmers tried to imagine how their farmland would look once the trees had grown, or once their woodland was thinned.

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Among many other important decision making factors, sustainable management should also take into account the visual impact on the landscape. However, the effect of management options is not easy to determine, and even if the forest manager does have a relatively good knowledge of the future visual aspect of a woodland, this is often difficult to convey to decision makers and to the public. Representing landscapes has always been a difficult task, and maps have been used since the 16th century, often combined with some idea of perspective, such as 'bird's-eye' views in hemispheric maps (Perrin 1993). Forest managers generally use simple three-dimensional drawings representing the layout of forest plots, before and after harvesting or planting. In addition to these mostly abstract representations, photography is often used, but it does not allow for simplified views, nor for time changes. Photographs can be modified manually to provide some idea of future development (Tress and Tress 2000). However, maps are generally favoured by land planners to represent development plans, for their rigour and possibility of quantification.

Geographic information systems (GIS) are modern computer tools providing a spatialised database. The 2-dimensional maps produced provide a great amount of information, which is often used to represent land-use and its changes. However, the three-dimensional visualisation techniques, such as image draping, proposed by most commercial GIS producers remain too restrictive to represent large landscapes in a satisfactory way.

AMAP, the vegetation and landscape modelling software initially developed at the CIRAD plant modelling unit[2], includes a set of applications for modelling and staging three-dimensional shapes, mainly plants (Reffye et al. 1989; Jaeger and Reffye 1992; Reffye et al. 1995). The computer graphics images produced allow for a dynamic and realistic reproduction of the third dimension. The fourth dimension (time) can also be accounted for by the plant growth engine, which produces plants at any age or season, taking into account their natural morphological development. The Imago Metropolis project has recently developed a new software, IMAGIS, which aims at representing in a photo-realistic way the information contained in a GIS (Perrin et al. 1999). It is an interactive tool which enables the user to process the information contained in a GIS database, to create and manipulate three-dimensional scenes made of groups of 3-D shapes representing the content of the different geographic objects, to choose a viewpoint of this scene, and to compute the corresponding image with the AMAP software.

Although the AMAP landscape visualisation software has received some attention by forest managers (Lecoustre et al. 1997), up to now it has been mainly used and developed for the purposes of urban landscape planning. In the present work, one of the farms surveyed by Étienne and Rapey (1999) was used as a case study to visualise the environmental changes induced by various forestry and agroforestry management techniques.

Materials and Methods

The present case study concerns the farm of Cessous described by Étienne and Rapey (1999). It is located in the Cévennes, a mountainous area at the northern limit of the French Mediterranean region, at an altitude of 350 m. It covers the two aspects of a micro-catchment on sandstone and schist soils. The farm was established in 1978 on 50 contiguous hectares dominated by natural regeneration of maritime pine (*Pinus pinaster*) and some abandoned terraces invaded by broom. Vegetation on the western half of the farm was totally destroyed

2 The AMAP software is now commercialised and further developed by Bionatics (http://www.jmg-graphics.com/amap.htm). This includes the GENESIS© plant growth engine and the ORCHESTRA© landscape design and rendering software.

by a forest fire in 1985. Since 1986 the agricultural system, based on organic agriculture specialised in berries transformed *in situ* for an up-market label, has been complemented by providing food and lodging to agri-tourists. Agroforestry was introduced in the farm in 1989 by planting a 1.2 ha experimental plot based on red oak (*Quercus rubra*).

The present farm structure is summarised in Table 1. The GIS MapInfo© was used to describe land tenure, land use units, soil potentiality and farm equipment (tracks, buildings, fences and water points) on the basis of cadastral charts, recent aerial photographs and surveys (Figure 1).

Table 1. Structure of the Cessous farm.

Type of land-use	Area	Woody species present
Dense woodland	15 ha	*Abies nordmanii, Alnus cordata, Betula pendula, Castanea sativa, Cedrus atlantica, Pinus nigra subsp. laricio, Pinus pinaster, Quercus ilex*
Open woodland	8 ha	*Populus nigra*
Agroforestry	8 ha	*Acer latanoides, Prunus avium, Quercus rubra, Tilia cordata*
Orchard	3 ha	*Prunus armeniaca, Prunus cerasus*
Shrubland	14 ha	
Pasture	2 ha	

Figure 1. Cessous land use. The star indicates the position of the camera.

A digital elevation model was built from the national survey map (IGN©) at the 1/25 000 scale.

This information was then transferred to IMAGIS© (Imago Metropolis consortium; http://imagis.cirad.fr/), which performs a selective reading of geographic data output by the GIS and transforms them in its proprietary format. This software enriches the synthetic description of landscape features contained in GIS entities according to their attribute in order to obtain the desired modelling and rendering level. The scene generator module automatically creates a three-dimensional scene corresponding to the template information provided by the GIS and the user-defined links, such as tree species, age, density, plantation pattern or natural regeneration (Barczi et al. 2000).

Individual tree computer mock-ups were computed for each species present, at the desired age, with the GENESIS© plant growth engine. These are based upon the botanical concepts developed by the Montpellier school of Botany (Hallé and Oldeman 1970; Reffye et al. 1989). The IMAGIS communication protocol sends sets of instructions to the ORCHESTRA© landscape design and rendering software, which then generates an image from the content of a scene, by setting the viewing parameters.

Results

A viewpoint was chosen for the present work on the track to the northwest of the area (the star on Figure 1), and the 'camera' oriented towards the southeast, in order to view a wide variety of land-use options. Scenes were computed for the following management options:

- Scene 1: the present situation (Figure 2);
- Scene 2: simulation of the same scene after 20 years (Figure 3);
- Scene 3: the same as Scene 2 after a silvopastoral re-spacing (50% thinning) of all the forested areas (Figure 4);
- Scene 4: a new simulation with the nearest plot clear-cut and replanted in cedar (Figure 5); and
- Scene 5: the same as Scene 4, after another 20 years, with agroforestry plots clear-cut and replanted (Figure 6).

Figure 2. Visualisation of Cessous with the present land-use.

Figure 3. Visualisation of Cessous with the present land-use after 20 years.

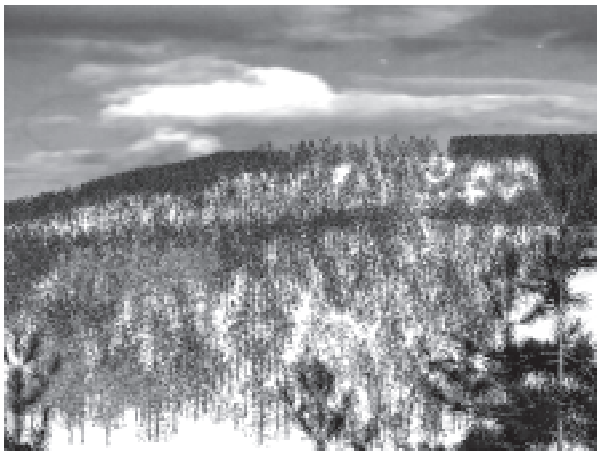

Figure 4. The same as Figure 3 after a silvopastoral re-spacing of all the forested areas.

Figure 5. Simulation with the nearest plot clearcut and replanted in cedar.

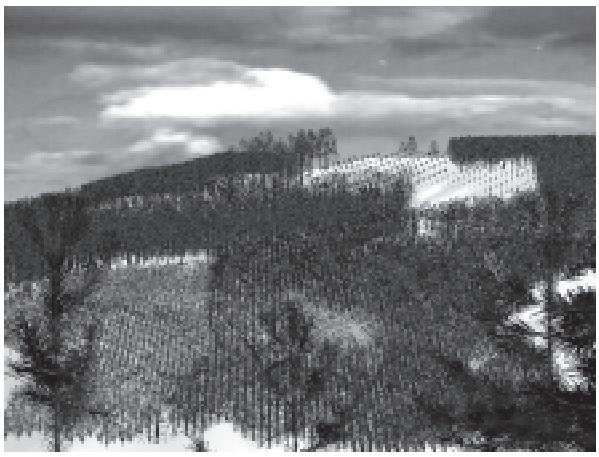

Figure 6. The same as Figure 5, after another 20 years, with agroforestry plots clearcut and replanted.

Colours are an important feature of the landscape, and differences between Spring and Autumn were considered important by the land manager. The two seasons were incorporated in the study; however, they cannot be represented in the black-and-white figures presented here.

Discussion

The coupling of a geographical information system with a landscape visualisation software provides the possibility to present to land managers different options and their result on the landscape. Various management options have been tested here:

- thinning, or more precisely ‘re-spacing’ in order to allow for grass to grow between the trees for a silvopastoral management;
- clear-felling;
- some trees have been pruned, but this treatment is in the background and cannot be observed on the figures presented; and
- replanting of the same or other tree species.

This work is still in progress, and requires permanent exchanges with the land manager. The first study by Étienne and Rapey (1999), concerning a resource dynamics model, resulted in modifications of the management plan by the landowner. Further work will involve not only the dynamics of the productive resources, but also the impact of the territorial layout on the visual aspects of the farm environment. Different points of view will be presented to the landowner, in particular scenes viewed from the apartments used for agri-tourism.

A great number of landscape visualisation computer packages can be found either through research and education or as commercial software (McGaughey 1997). Many offer the possibility of adding special effects (such as sky background, fog or haze, snow cover, sunlight and shade, mirror effect of lakes, etc.) providing very realistic images (Buckley et al. 1998). In addition to these common computer graphics effects, the plant growth simulator developed at the CIRAD plant modelling unit provides three-dimensional images which are not simply generated from artificial graphic symbols, but are based on architectural models built from botanical observations and measurements, including natural variability based on

stochastic models. The plant growth engine creates virtual plants that are closely linked to reality, and that grow according to the observed growth.

The black-and-white figures presented in this paper are quite simple, but for discussion with the land manager more realistic images were computed. With the progress in computer hardware these can be displayed on small laptop computers, but large screens can be preferable, or projections through data viewers, depending on the public.

However, such 'hyper-realistic' images may prove unnecessary for planning purposes. They may even produce an opposite effect if the 'seduction' they provide reduces the necessary critical distance between the virtual model and the observer (Perrin 1993). The perception and aesthetic evaluation of a landscape can be analysed according to three organisation levels: an objective dimension (formal landscape organisation, proportion, composition rhythm of various biophysical elements); a cultural dimension (related to social groups, to history, to representations of nature); and an individual subjective dimension (Sauget and Depuy 1996). The selected representation of landscape induces its own effects, and the making of the decision in a management project should refer to various disciplines, such as psychology, sociology, etc. Such questions will be the object of further collaborative work with agroforesters, computer scientists, geographers and landscape ecologists. Computer graphic representations must be considered as one decision support system among others, which must be used to help communicate in addition to other more conventional methods.

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Development and Testing of a Criteria and Indicators System for Sustainable Forest Management at the Forest Management Unit Level: Case Study at the Haliburton Forest & Wild Life Reserve Ltd., Ontario, Canada.

Thorsten Mrosek and David Balsillie

University of Toronto, Faculty of Forestry
Toronto, Ontario, Canada

Abstract

The development and implementation of sets of Criteria and Indicators (C&I) for Sustainable Forest Management (SFM) has shown significant progress at the international and national level, but require refinement and testing at the Forest Management Unit (FMU) level. There is also a lack of demonstrable case studies showing the application of advanced C&I at the local level. The University of Toronto has been conducting research on the development and testing of a C&I System for SFM at the FMU level since January, 1998. This Case Study takes place at the Haliburton Forest & Wild Life Reserve Ltd. in Ontario, Canada. The selected mixed-wood forest of 23 800 ha is highly suitable because of its advanced integrated, multiple use and nature-oriented forest management concept. The study is based on the hypothetical suitability of C&I for defining, measuring, analysing, assessing and monitoring sustainability at the FMU level. The objectives of the project are to develop a C&I System which consists of an optimum and minimum Generic C&I Set, which also has applicability for the SFM of temperate forests internationally, and can be utilized as an adaptive management system. The methods applied for the development and testing of the C&I System for SFM include: the review of principles, C&I, verifiers and norms for SFM at various levels; the selection and development of the optimum and minimum Generic Set of C&I for SFM at the FMU level; the identification of verifiers and norms for the Case Study area; the testing of the Generic C&I Set as a Case Study; the development of a database of indicator measurements and the application of a geographic information system; the

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assessment of the state of the forest and forest management practices; the application of adaptive management procedures; and the evaluation of the suitability of the C&I System for sustainability determination. The preliminary Generic C&I Set was developed mostly based on the outcomes of the Center for International Forestry Research North American Test of C&I for Sustainable Forestry. This C&I Set is currently in the process of field testing. The C&I System consists of a sequence of generic modules which can be applied internationally in temperate forests by specifying and addressing local conditions. These modules are: the formulation of goals and objectives for the FMU; the identification of local forest management standards for defining indicator norms; the application of the set of C&I; the assessment of C&I performance in comparison to objectives and norms, as well as the application of adaptive management procedures. An example of the above modular System is provided for the indicator 'Vegetation types and structural classes relative to the historical conditions'. A progress report on the C&I implementation and testing Case Study, and an evaluation of the entire research project, are presented.

Keywords: sustainable forest management, Criteria and Indicators system, case study, certification, adaptive management

1. Introduction

During the last decade, international efforts towards achieving sustainable forestry at various levels have shown significant progress. The concept of Criteria and Indicators (C&I) has become widely accepted as a suitable tool for forest policy, management and research for conceptualizing, evaluating and implementing Sustainable Forest Management (SFM) (Wijewardana et al. 1998). Based on research mostly conducted within the Center for International Forestry Research (CIFOR) C&I project, suitable C&I methodology has recently been developed in the form of the C&I toolbox (CIFOR 1999a). The development and implementation of sets of C&I for SFM has shown significant progress at the international and national level, but requires further refinement and testing at the local Forest Management Unit (FMU) level. Major conceptual and methodological problems remain to be addressed within the research field of C&I for SFM, and there is a lack of demonstrable Case Studies and C&I field testing at the local FMU in particular.

The Faculty of Forestry, University of Toronto, has been conducting a research project on the development and testing of a C&I System for SFM at the FMU level since January, 1998. The project is taking place as a Case Study at the Haliburton Forest & Wild Life Reserve Ltd. in Ontario, Canada.

The study is based on the hypothetical suitability of C&I for defining, measuring, assessing and monitoring sustainability at the FMU level. The objectives of the project are to develop a C&I System for SFM which consists of an optimum and minimum Generic C&I Set, which also has applicability for temperate forests internationally, and can be utilized as an adaptive management decision-making support system.

This paper introduces this C&I System for the evaluation of SFM and presents the Haliburton Forest as a suitable Case Study for the field testing of the C&I System. After introducing the Case Study area and describing the methodology applied, preliminary results are presented in the form of the C&I System, the C&I Set and its field testing. The method is discussed critically and conclusions concerning the suitability of the C&I concept for the evaluation of sustainability in forestry are provided.

2. Method

2.1 Study area

The research project takes places as a Case Study at the Haliburton Forest & Wildlife Reserve Ltd. (Haliburton Forest) in Ontario, Canada. This privately owned forest covers 23 800 ha, of which 19 000 ha are forested. It is located 270 km northeast of the City of Toronto. The Haliburton Forest lies in the Great Lakes – St. Lawrence Forest Region, and is characterized by tolerant hardwood forest types dominated by sugar maple (*Acer saccharum*). The forest consists of 24 tree species, includes approximately 50 lakes and 250 wetlands, and is characterized by an associated diversity of wildlife (e.g. 149 bird species). Although the forest was heavily harvested historically in the form of high grading (partial harvest removing only the most desirable trees altering the quantity and quality of the residual stand) (NRC CFS 1995), its overall naturalness and natural diversity are still high, and a forest conservation concept, including a protected areas network, has been implemented (Mrosek 1998; Mrosek 2001). A selection cut silvicultural system (regeneration of the forest and maintenance of its uneven-aged structure by harvesting some trees in all age classes either as single trees or in small groups) (NRC CFS 1995) is currently being applied.

In addition to its suitable area size, ownership type and natural diversity, the selected forest is highly suitable as a Case Study because of its advanced integrated, multiple use and nature-oriented forest management concept. This sustainable forest management concept aims at integrating multiple forms of forest use (e.g. timber harvesting, hunting, camping, canoeing, snowmobiling and outdoor education) with aspects of forest ecology and conservation. The Haliburton Forest is a multi-purpose forest operation with timber harvesting contributing only 22% of the overall income as shown in Figure 1. (Schleifenbaum 1998). In February 1998, the Haliburton Forest was the first FMU to be certified by the Forest Stewardship Council (FSC) in Canada (SmartWood 1998).

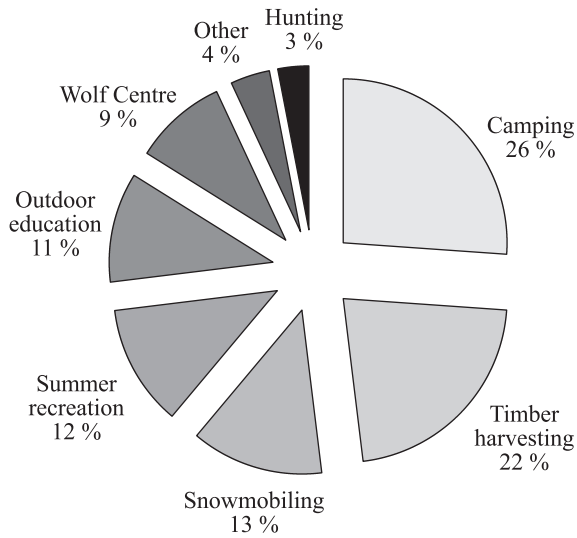

Figure 1. Haliburton Forest income distribution indicating the importance of multiple forest use (Schleifenbaum 1998).

2.2 Methods

The development of the C&I System for SFM was partly based on the Tropenbos Hierarchical framework for the formulation of SFM standards (Lammerts van Bueren and Blom 1997) and the Canadian Standards Association (CSA) Sustainable forest management system (CSA 1996).

The methods applied for the development and testing of the C&I System include in summary: the review of principles, C&I, verifiers and norms for SFM at various levels; the selection and development of the optimum and minimum Generic Set of C&I for SFM at the FMU level; the identification of verifiers and norms for the Case Study area; the testing of the Generic C&I Set as a Case Study; the development of a database of indicator measurements and the application of a geographic information system; the assessment of the state of the forest and forest management practices; the application of adaptive management procedures; and the evaluation of the suitability of the C&I System for sustainability determination. These methods are presented in more detail.

As the basis for the selection of suitable C&I, the review of C&I for SFM at various levels (local, regional, national, international) included the analysis of all major processes for C&I development and testing for temperate forests internationally (e.g. Montreal and Helsinki processes), as well as all major C&I sets (e.g. Canadian Council of Forest Ministers C&I) and C&I methodology (e.g. CIFOR methodology).

The selection and development of the optimum and minimum Generic C&I Set, in the following referred to as the Generic C&I Set, was mostly based on the outcomes of the CIFOR North American Test (NAT) of C&I for Sustainable Forestry (Woodley et al. 1998a). Three indicators from the CIFOR Generic Template (C&I Tool No. 2) (CIFOR 1999b) and five new indicators were incorporated in order to supplement the NAT C&I Set, where required. Furthermore, the C&I of the original sets were organized and labeled in a more consistent way and some indicators were reformulated and modified. The CIFOR Guidelines for Developing, Testing and Selecting Criteria and Indicators for Sustainable Forest Management (C&I Tool No. 1) (Prabhu et al. 1999) were applied in this process.

The identification of indicator verifiers and norms, defined in accordance with the hierarchical C&I framework (Lammerts van Bueren and Blom 1997), specifies suitable indicator measurement methods and threshold values for indicator performance respectively. This process is based on regional and local expert knowledge.

A verifier is defined as “the source of information for the indicator or for the reference value for the indicator” (ibid., p. 25). A variety of verifiers are used for indicator measurement based on generally accepted field methods and data availability for the FMU.

A norm is defined as “the reference value of the indicator and is established for use as a rule or a basis for comparison” (ibid., p. 24). Indicator norms are currently in the process of being defined for the FMU, using three quantitative or qualitative threshold classes. Assigning indicator measurements to one of these three normative classes allows a basic trend analysis (positive, neutral or negative indicator performance) towards sustainability for the indicator under investigation (Stecker 1998). The selection of indicator norms for the Haliburton Forest is mostly based on the FSC Great Lakes – St. Lawrence (GLSL) forests regional standards (GLSL Regional FSC Initiative Steering Committee 2000).

Concerning the field testing of the C&I System and Set as a Case Study at the Haliburton Forest, a number of measurement methods were applied in accordance with the verifiers identified for each indicator.

The methods that were applied for field testing the C&I relating to Principle 1 (Maintenance of Ecological Integrity) included: the analysis of existing forest management planning and inventory data; a World Wildlife Fund Canada special landscape features gap analysis; a biodiversity evaluation (Mrosek et al. 1999); the establishment of 19 permanent

sample plots in representative reference forests applying the method of the Ontario Ministry of Natural Resources Forest Growth and Yield Program (Hayden et al. 1995); the application of an integrated forest survey technique; and the application of an ecological land classification system (Chambers et al. 1997).

The methods that are currently being applied for the field testing of the C&I of the remaining Principles 2, 3 and 4 include: the analysis of existing forest management planning and inventory data; harvest damage assessment techniques; a recreational use impact analysis; economic performance audit methods; a forest policy analysis; a community and stakeholder survey; and a forest values and stakeholder participation survey.

All indicator measurements are currently in the process of being stored in a comprehensive database. A geographic information system (ARC/INFO and ArcView) was established and applied for the measurement and analysis of spatial indicators and improved data management.

The assessment method applied will be a multi-criteria analysis rating method based on the CIFOR Guidelines for Applying Multi-Criteria Analysis to the Assessment of Criteria and Indicators (C&I Tool No. 9) (Mendoza et al. 1999). A ranking method assigning weight factors to each decision element will not be applied due to the uncertainty related to the importance of each element and the relationships between them. However, a hierarchical rating method will be applied to all principles, criteria and indicators. Scores will be assigned to each normative indicator measurement class (3 = positive, 2 = neutral and 1 = negative indicator performance). The scores of all indicators will be aggregated for each criterion and the summary scores for each criterion aggregated for each principle. Finally, an overall sustainability index can be calculated based on all aggregated scores.

Thereby, the application of this hierarchical rating method will allow the assessment of each decision element, as well as the overall assessment of sustainability for the FMU under investigation. This will also allow for a comparison with other similar FMUs.

Adaptive management procedures will be applied in order to formulate recommendations for addressing identified shortcomings.

Finally, the C&I System will be evaluated concerning its suitability for the determination of sustainability by applying the CIFOR Guidelines for Developing, Testing and Selecting Criteria and Indicators for Sustainable Forest Management (C&I Tool No. 1) (Prabhu et al. 1999).

3. Preliminary Results

3.1 C&I System

The C&I System consists of a sequence of generic modules which can be applied internationally in temperate forests by specifying and addressing local conditions. These modules are logically related to each other, and therefore, should be applied in sequence. However, the modules have specific functions that could also be of some value if applied separated from the overall system.

The modules are in summary: the formulation of goals and objectives for the FMU; the identification of local forest management standards for defining indicator verifiers and norms; the application of the Generic Set of C&I; the assessment of C&I performance in comparison to objectives and norms, as well as the application of adaptive management procedures. The complete C&I System is shown in Figure 2.

In the following section each module is presented in some detail, and an example for the application of the above modular System is provided for Indicator 1.2.2 (Area of vegetation types and structural classes relative to the historical condition and total forest area).

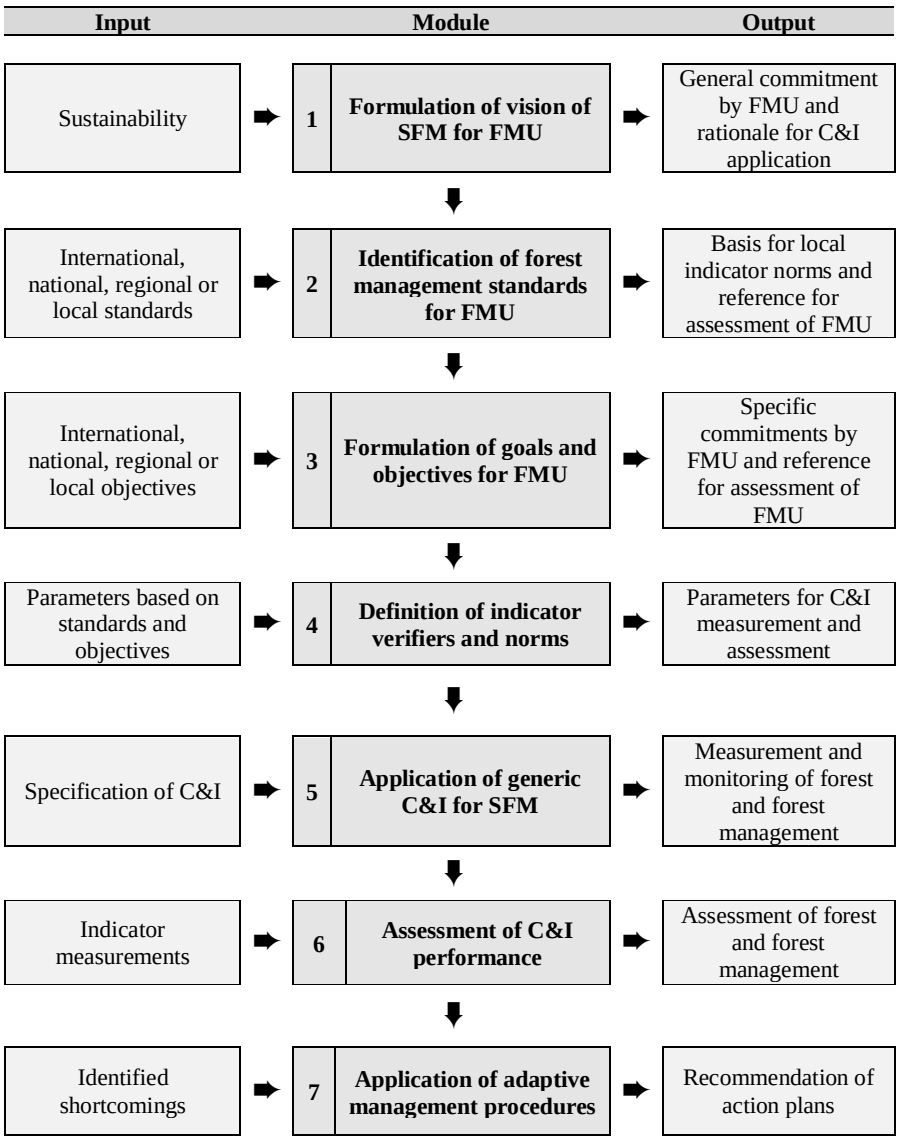

Figure 2. C&I System for the application of the Generic C&I Set for SFM at the local FMU level in temperate forests.

Module 1 (Formulation of vision of SFM for FMU) serves as a general commitment by the FMU and is the rationale for the C&I application. The Haliburton Forest defined its vision of sustainable forestry in 1984 and has been working on its realization since that time (Schleifenbaum 1993, 1998).

Module 2 (Identification of forest management standards for FMU) is based on expert knowledge and serves as the basis for the formulation of indicator norms and as a reference for the assessment of the FMU in the international, national, regional or local context. In this context, a forest management standard is generally defined as a common understanding of good forestry practices with relevance and applicability to the FMU under investigation.

Forest management standards for the Haliburton Forest area are formulated mostly based on the FSC Great Lakes – St. Lawrence (GLSL) forests regional standards (GLSL Regional FSC Initiative Steering Committee 2000). For example, standards for the Haliburton Forest area require the application of a nature-oriented silvicultural system.

Module 3 (Formulation of goals and objectives for FMU) serves as a specific commitment by the FMU and is used as an additional reference for the assessment of the FMU. It is also based on expert knowledge. The Haliburton Forest has a comprehensive hierarchical target system for its integrated, multiple forest use operation (Schleifenbaum 1998). For the example indicator, the general objective is the mimicking of the natural forest and its disturbance regime. The specific objective is the maintenance of the natural stand type distribution and representation of the entire range of their natural development phases (e.g. old growth phase) and structural classes.

Module 4 (Definition of indicator verifiers and norms) specifies indicator measurement methods and performance parameters based on the selected standards and objectives. A verifier is defined as "the source of information for the indicator or for the reference value for the indicator" (Lammerts van Bueren and Blom 1997, p. 25). A norm is defined as "the reference value of the indicator and is established for use as a rule or a basis for comparison" (ibid., p. 24). Suitable verifiers for most indicators have been selected, but the formulation of norms providing threshold values is still in progress. The verifier for the example indicator is the analysis of the forest resource inventory and the data from the permanent sample plots. The corresponding norms defining threshold values for each species, stand type and structural class are defined relative to the historical condition and in accordance with regional or local expert knowledge.

Module 5 (Application of the Generic C&I Set for SFM) measures and monitors the forest and its management. The preliminary Generic C&I Set consists of four principles, 16 criteria and 58 indicators. The complete set is presented in the Appendix. At the time of writing, approximately 50% of all indicators have been implemented and tested at the Haliburton Forest, and the measurement of the remaining indicators will be completed by the end of the year 2000. The example indicator measures the area of the vegetation types and structural classes, relative to the historical condition and the total forest area. A detailed description of the C&I Set and definitions of principles, criteria and indicators are provided in Chapter 3.2 (Criteria and Indicators Set).

Module 6 (Assessment of C&I performance) is based on the indicator measurements. The hierarchical assessment of principles, criteria and indicators based on the rating of each indicator leads to the overall assessment result of sustainability of the FMU under investigation and allows comparisons with other similar FMUs. Due to the ongoing development of indicator norms, the assessment of C&I performance is still in progress. The measurements for the example indicator have been assessed relative to the historical condition and in reference to the objective of maintaining the natural stand type distribution and representing the entire range of natural forest development phases and structural classes.

Module 7 (Application of adaptive management procedures) recommends action plans in order to address identified shortcomings. This module is still in development due to the ongoing analysis and assessment. For example, a modification of the silvicultural system may be recommended in order to address the identified shift in the stand type distribution and tree species composition towards tolerant hardwoods.

3.2 C&I Set

The preliminary Generic C&I Set for SFM at the local FMU level in temperate forests was developed applying the Tropenbos Hierarchical framework for the formulation of SFM standards (Lammerts van Bueren and Blom 1997). This framework describes "hierarchical

levels (principles, criteria and indicators) to facilitate the formulation of a set of parameters in a consistent and coherent way. It describes the function of each level as well as the common characteristics of the parameter appearing on a level" (ibid., p. 15). Within this hierarchical framework, a principle is defined as "a fundamental law or rule, serving as a basis for reasoning and action. Principles have the character of an objective or attitude concerning the function of the forest ecosystem or concerning a relevant aspect of the social system that interacts with the ecosystem. Principles are explicit elements of a goal, e.g. sustainable forest management" (ibid., p. 18). A criterion is defined as "a state or aspect of the dynamic process of the forest ecosystem, or a state of the interacting social system, which should be in place as a result of adherence to a principle. The way criteria are formulated should give rise to a verdict on the degree of compliance in an actual situation" (ibid., p. 20). Finally, an indicator is defined as "a quantitative or qualitative parameter which can be assessed in relation to a criterion. It describes in an objectively verifiable and unambiguous way features of the ecosystem or the related social system, or it describes elements of prevailing policy and management conditions and human driven processes indicative of the state of the eco- and social system" (ibid., p. 22).

The preliminary Generic C&I Set for SFM at the local FMU level in temperate forests consists of four principles, 16 criteria and 58 indicators, and is currently in the process of field testing. The complete set is presented in the Appendix.

The C&I Set of the North American Test (NAT) was chosen as the platform for the Generic C&I Set because: it is the most recent test incorporating the CIFOR Phase 1 C&I and the Canadian Council of Forest Ministers C&I; it applied the most advanced CIFOR C&I testing methodology; the test was aimed at the local FMU level; and it took place under temperate forest conditions. The NAT C&I are clearly defined and include general information of the screening procedure concerning the C&I attributes, applicability to different types of ownership, appropriate scale of application, characteristics, functions, underlying concepts, relevance, measurement methods, data requirements, practicality and information value (Woodley et al. 1998b).

The Generic C&I Set is characterized by the following modifications and extensions of the original set of the NAT of C&I for Sustainable Forestry (Woodley et al. 1998a).

Concerning the C&I of Principle 1 (Ecological integrity is maintained), the order of all C&I has been changed according to the following logical hierarchy of forest ecosystem elements: landscape factors, ecosystem diversity, ecosystem functions, species diversity, genetic diversity, environmental factors and external stress factors.

Criterion 1.1 (Landscape patterns are maintained) has been modified from the original NAT landscape criterion (NAT 1.2) in order to broaden the range of landscape factors under consideration. Indicator 1.1.3 (Extent to which forest management considers the protection of unique or significant landscape level features) has newly been developed and added in order to ensure that special features which are unique or significant at the landscape level and occur in the FMU are considered sufficiently.

Concerning Criterion 1.3 (Ecosystem function is maintained), Indicator 1.3.1 (Area and representativeness of protected areas for enabling natural processes as well as habitat and species protection) has been moved and modified from the original NAT indicator (NAT 1.3.1) in order to take into consideration the conservation of habitat and natural dynamics. The original NAT natural disturbance indicators (NAT 1.1.3 and 1.1.4) have been aggregated to Indicator 1.3.4 (Area and severity of natural disturbances by storms, insects, wildfire etc.) because the difference between these disturbance factors was seen as not significant from a methodological perspective.

Concerning Criterion 1.4 (Native species diversity is maintained), Indicator 1.4.2 (Number of known indigenous species classified as extinct, extirpated, endangered, threatened or

vulnerable relative to the total number of indigenous species) has been modified from the original NAT indicators (NAT 1.3.3 and 1.3.4) in order to take into consideration all indigenous species occurring in a FMU, including non-forest and aquatic species. Indicator 1.4.3 (Species protection and restoration programs for endangered, threatened, vulnerable or rare species) has been added in a modified form from the CIFOR generic template (CIFOR 2.2.4) in order to incorporate this elemental forest conservation component which is not covered sufficiently by the original NAT indicator (NAT 1.3.1).

Concerning Criterion 1.5 (Genetic diversity is maintained), all indicators from the original NAT C&I Set (NAT 1.6.1 to 1.6.3) were accepted.

Concerning Criterion 1.6 (Physical environmental factors), Indicator 1.6.1 (Area and percentage of harvested area with degraded soil quality (e.g. soil compaction, displacement, erosion, puddling and loss of organic matter)) has been modified from the original NAT indicator (NAT 1.7.1) because the normative element of a specified area percentage should be covered by norms and not by indicators. Indicator 1.6.2 (There is no significant change in the quality and quantity of water from the forest catchment) from the CIFOR set (CIFOR 2.1.7) replaced the original NAT indicator (NAT 1.7.2) because it appeared to be more suitable to cover the whole range of aquatic ecosystem variables such as the water quality of lakes and streams in the FMU.

Concerning Criterion 1.7 (Incidence of disturbance and stress), Indicator 1.7.2 (Pollutant levels (emissions) and chemical contamination (e.g. herbicides and pesticides) in the ecosystem) has been modified from the original NAT indicator (NAT 1.5.1) in order to consider anthropocentric stress in the form of chemical applications as silvicultural prescriptions.

Concerning the C&I of Principle 2 (Yield of goods and services are sustainable), Criterion 2.1 (Policy, planning and institutional framework are conducive to sustainable forest management) has been deleted in order to avoid overlap with the same criterion under Principle 4 (Enabling conditions for SFM) and Criterion 2.3 (The management plan is implemented and effective in moving toward stated goals) has been moved to Principle 4 because it was seen as an integral part of the enabling conditions of the management system.

With regard to Criterion 2.1 (Forest management provides for sustainability of goods and services), two original NAT indicators (NAT 2.2.1 and 2.2.2) have been moved to Principle 4 because they relate to the enabling conditions of the forest policy and management framework. Indicator 2.1.1 (Land base available for timber production) has been modified from the original NAT indicator (NAT 2.2.7) because from a conceptual perspective, a trend analysis has to be part of all indicator definitions or will be a result of continued monitoring. Indicators 2.1.6 (Recreational use management provides recreational services while minimizing impact on wildlife and environment) and 2.1.7 (Wildlife management provides hunting opportunities and is ecologically oriented and sustainable) have been developed and added in order to sufficiently address these elemental multiple forest use management issues.

Concerning Criterion 2.2 (Forest management is socially efficient), Indicator 2.2.1 (Availability and use of recreational opportunities are maintained and other non-timber values are provided) has been modified from the original NAT indicator (NAT 2.4.1) in order to integrate the provision of other non-timber values such as educational or spiritual values. Indicator 2.2.2 (Economic importance of non-timber products and services) has been modified from the original NAT indicator (NAT 2.4.2) in order to cover the economic importance of non-timber products and services for the FMU in more general terms. Indicator 2.2.3 (Existence of economic rents (total management revenues exceed management costs)) has been modified from the original NAT indicator (NAT 2.4.3) in order to provide for the evaluation of the entire economic performance of multi-purpose forestry operations and not just the traditional harvest operation.

Concerning the C&I of Principle 3 (Society accepts responsibility for sustainability), only NAT Criterion 3.3 (Forest-based human health issues) has been moved to the end.

With regard to Criterion 3.1 (Forest management provides ongoing access to the resource), Indicator 3.1.1 (Access to resource is fair and secure) has been modified from the original NAT indicator (NAT 3.1.1) because, at least under temperate forest conditions, the actual assessment of the access to the forest appears to be more appropriate than the evaluation of the perception of it.

Concerning Criterion 3.2 (Concerned stakeholders have a right to participate in open and meaningful public participation processes in order to influence management), Indicator 3.2.4 (The decision-making process is transparent and considers the interests and values of stakeholders) has been modified from the original NAT indicator (NAT 3.2.4) in order to ensure that the interests of stakeholders are considered as well. Indicator 3.2.5 (Extent to which forest management considers the protection of unique or significant sites of social, cultural, spiritual or scientific importance) has been created in order to complement the original NAT indicator (NAT 3.4.3) by considering special social, cultural, spiritual or scientific sites of importance for non-aboriginal people as well.

Concerning Criterion 3.3 (Recognition and respect for Aboriginal roles in sustainable forest management (Aboriginal rights, Treaty rights and aboriginal values)), Indicator 3.3.2 (Extent of Aboriginal participation in forest-based opportunities) has been modified from the original NAT indicator (NAT 3.4.2) because referring to an assessment appeared to be unnecessary. Indicator 3.3.3 (Extent to which forest management considers the protection of unique or significant Aboriginal social, cultural or spiritual sites) has been modified from the original NAT indicator (NAT 3.4.3) in order to cover forest management completely, considering not only planning but also the plan implementation.

Concerning Criterion 3.4 (There is equitable access to and distribution of economic rents), Indicator 3.4.1 (Economic importance of FMU for local communities) has been modified from the original NAT indicator (NAT 3.5.5) in order to relate the indicator more closely to the FMU. At the local FMU unit level, not only the economic importance of forestry in general, but the importance of the FMU under investigation for local communities is most relevant for its sustainability. Indicator 3.4.2 (Employment of local population at FMU) has been modified from the original NAT indicator (NAT 3.5.3) because in a multiple forest use operation, not only the employment in forest management, but the entire employment in the FMU has to be considered. Indicator 3.4.3 (Distribution of rent capture) has been reformulated from the original NAT indicator (NAT 3.5.4) because referring to an estimate appeared to be unnecessary.

Concerning Criterion 3.5 (Forest based human health issues), Indicator 3.5.2 (Forest management cooperates with public health authorities concerning forest-related illnesses) has been reformulated from the original NAT indicator (NAT 3.3.1) in a more general way to in order to address temperate forest conditions.

Concerning the C&I of Principle 4 (Enabling conditions for SFM), some indicators (NAT 2.2.1 and 2.2.2) from the original NAT Criterion 2.2 and the entire NAT Criterion 2.3 have been moved here.

Concerning Criterion 4.1 (Policy, planning and institutional framework are conducive to sustainable forest management), Indicator 4.1.1 (Forest management considers and meets legal forestry requirements and standards) has been developed and added in order to incorporate the elemental forestry standard of meeting legal requirements.

3.3 C&I field testing

Within the scope of this paper, only selected C&I field testing results for Principle 1 (Ecological integrity is maintained) are presented. Because the selection of indicator verifiers

and norms has not yet been completed, only preliminary data for each indicator are provided. The full field testing results covering the entire C&I Set and including verifiers and norms will be presented in subsequent papers.

Concerning the indicators of Criterion 1.1 (Landscape patterns are maintained), forest fragmentation is very limited and the connectedness of the forest components is maintained. Forest cover on the FMU is high with 19 000 ha forested out of a total area of 23 800 ha (79%). The remaining area is covered by lakes and wetlands (Indicator 1.1.1). The forest road network density is low, being 13.7 m/ha (7.5 m/ha for gravel roads and 6.2 m/ha for trails) (Indicator 1.1.2). Landscape features of special concern occurring in the FMU are identified and considered by the forest management. For example, an isolated population of red spruce (*Picea rubens*) outside of its natural range occurs at the Haliburton Forest and is under special management (Schleifenbaum 1998) including the protection of its core area in the form of a reserve (Indicator 1.1.3).

Concerning the indicators of Criterion 1.2 (Ecosystem diversity is maintained), the total forest area is maintained and forest conversion into non-forest land cover has not taken place (Indicator 1.2.1). The area and percentage of forest types relative to the total forest area and the historical condition are shown in Table 1.

Table 1. Area and percentage of tree species relative to the total forest area and the historical condition (data available only for some tree species) (Mrosek et al. 1999; Mrosek 2001).

Tree species	Area in ha (in year 1999)	Percentage of total forest area (in year 1999)	Historical percentage of total forest area (in year 1863)
Sugar maple (*Acer saccharum*), red maple (*Acer rubrum*) and other hardwoods	9206.3	49.4	28.3
Eastern hemlock (*Tsuga canadensis*)	2331.2	12.5	14.8
Yellow birch (*Betula alleghaniensis*) and white birch (*Betula papyrifera*)	2017.8	10.8	12.1
American beech (*Fagus grandifolia*)	1714.5	9.2	6.2
Red oak (*Quercus rubra*)	1035.2	5.6	1.8
Black spruce (*Picea mariana*), white spruce (*Picea glauca*) and red spruce (*Picea rubens*)	754.5	4.0	6.5
Balsam poplar (*Populus balsamifera*), Trembling aspen (*Populus tremuloides*) and largetooth aspen (*Populus grandidentata*)	724.0	3.9	-
Balsam fir (*Abies balsamea*)	422.8	2.3	7.5
Basswood (*Tilia americana*)	72.2	0.4	-
Eastern white cedar (*Thuja occidentalis*)	74.3	0.4	7.0
Black ash (*Fraxinus nigra*) and white ash (*Fraxinus americana*)	182.0	1.0	-
Eastern white pine (*Pinus strobus*)	31.5	0.2	11.5
Ironwood (*Ostrya virginiana*)	36.2	0.2	–
Tamarack (*Larix laricina*)	22.9	0.1	–

Although the natural diversity overall corresponds with the historical condition, a shift towards tolerant hardwoods has occurred due to previous high grading and present selection cut harvesting practices (Indicator 1.2.2) (Mrosek 2001). Forest dependent bird, salamander and ground beetles species have been selected as indicator species groups for key and sensitive guilds of the tolerant hardwoods of the Haliburton Forest, and ongoing monitoring shows that these indicator species groups occur in the community guild structure in a representative way (Indicator 1.2.3) (Mrosek et al. 1999).

Concerning the indicators of Criterion 1.3 (Ecosystem function is maintained), a protected areas network exists covering 6.2% of the total forest area and representing all natural forest types and their development phases. These protected areas serve for species and habitat conservation and are used as reference forests for the study of natural forest dynamics (Indicator 1.3.1) (Mrosek 1998; 2001). Ecologically sensitive areas such as wetlands are conserved, and buffer zones of 15 m (or one tree length) along significant lakes and rivers are protected (Indicator 1.3.2) (Schleifenbaum 1998). The measurements in permanent sample plots indicate that coarse woody debris and snags are retained at functional levels, but the analysis of the quantity and quality of downed woody debris and the number and quality of wildlife trees is still in progress (Indicator 1.3.3). Natural disturbances in the form of storms and insect infestations take place frequently and mostly in accordance with historical patterns. Wildfires are usually suppressed (Schleifenbaum 1998). The analysis of the actual size (area) of each disturbance factor is still ongoing (Indicator 1.3.4).

Concerning the indicators of Criterion 1.4 (Native species diversity is maintained), hunting, trapping and fishing data for large mammals, furbearers and fish harvest levels over the last 30 years and the monitoring of selected species and species groups, such as wolf (*Canis lupis*) and small mammals, indicate that the population levels of indigenous species are stable (Indicator 1.4.1) (Mrosek et al. 1999). The number of indigenous species being extinct, extirpated, endangered, threatened, vulnerable or rare at the global, national or regional level is low in comparison to the total number of indigenous species (Indicator 1.4.2) as shown in Table 2.

Table 2. Number of indigenous species being endangered, threatened, vulnerable or rare (extinct and extirpated not applying) at the global, national or regional level and total number of indigenous species at the Haliburton Forest (Mrosek et al. 1999).

Species Group	Number of theoretical species for FMU based on literature	Number of confirmed species for FMU based on field observations	Number of endangered, threatened, vulnerable or rare species for FMU
Plants	922	313	18
Mammals	56	33	5
Birds	207	149	27
Reptiles and amphibians	36	20	5
Fish	73	28	9

There are no known extinct or extirpated species from the Haliburton Forest, and protection and restoration programs are in place for endangered, threatened, vulnerable or rare species. For example, the decreasing tree species, white pine (*Pinus strobus*), has been protected from logging and is promoted by planting. Other protection and restoration programs include the maintenance of nesting boxes for the decreasing species, wood duck (*Anix sponsa*) (Indicator 1.4.3) (Schleifenbaum 1998).

The remaining C&I of Principle 1 have mostly been measured, but the analysis is still ongoing. The measurement, analysis and assessment of criteria and indicators of Principles 2, 3 and 4 are still in progress.

4. Discussion

4.1 C&I Concept

The concept of sustainability and SFM is widely accepted internationally to be suitable for protecting the world's forests and maintaining their integrity while allowing multiple forest use for current and future generations. The concept of C&I is seen as being suitable to define, promote, implement and evaluate the sustainability of forests and their management. Although the development and implementation of C&I for SFM has recently shown significant progress at various levels, major conceptual problems still remain to be addressed.

The concept of C&I for SFM is a holistic approach integrating the ecological, social, economic, policy and management dimensions of forests, which results in uncertainty concerning the analysis and assessment of these complex and linked systems. The theoretical basis for integrating ecological, social and economic indicators still needs to be developed (Woodley et al. 1998a) and remains to be fully demonstrated.

Sets of C&I for SFM at the local FMU level still need further refinement in terms of: optimizing the C&I selected; identifying the importance of indicators for assigning appropriate weight factors; defining suitable verifiers as indicator measurement methods and norms as quantitative or qualitative measurement units and threshold values in order to make indicator measurement and assessment meaningful; and improving the understanding of the functional linkages within the C&I sustainability model represented by quantitative or qualitative relationships between decision elements of the same hierarchical level (between indicators) and of different levels (between principles, criteria and indicators).

There is still need for C&I testing internationally and at the local FMU in particular, and there is still a lack of suitable case studies. The C&I testing should involve actual field testing rather than applying mostly theoretical screening procedures. Case studies should cover a variety of different FMU characteristics such as: suitable area size; different land ownership types, high naturalness and corresponding natural diversity; diverse multiple-purpose forest management; and comprehensive data availability for the entire range of SFM variables.

4.2 C&I System

The C&I System for SFM at the local FMU level consists of a sequence of generic modules for evaluating sustainability and is designed to be applied internationally in temperate forests while addressing specific local conditions.

This System approach allows for the formulation and application of an optimum and minimum Generic Set of C&I that increases consistency and comparability for the assessment of sustainability of FMUs internationally. Considering the variety of approaches for evaluating SFM internationally, a common definition of sustainability (where appropriate due to comparable conditions) is required. C&I measurement and analysis schemes should be standardized in order make assessment results between different FMUs meaningful and comparable. Also in terms of practicability, a Generic C&I Set is required, because it is not feasible for every FMU (e.g. small privately owned forests) to develop and test its own local C&I Set.

The consideration of specific local conditions is assured by incorporating expert knowledge based forest management standards and goals and objectives for the FMU into the evaluation system. By defining locally relevant indicator verifiers and norms based on this expert knowledge, specific local conditions are considered. Because these verifiers and norms are defined within the generic C&I framework, consistency and comparability are maintained.

Instead of assessing sustainability for each FMU based on individual expert assessments within the C&I application, it is preferable to develop general indicator norms based on regional standards that allow for the assessment of a FMU within this region, based on its specific C&I application. The definition of indicator norms and the design of the assessment method follow a conservative approach due to the limited scientific understanding of the complex multiple dimensions of forests and their functional relationships. A basic trend analysis applying three measurement units or threshold values for each indicator norm appears to be suitable, considering the scientific uncertainty of quantitative and qualitative performance standards and threshold values for indicators. For the same reason, only a basic, but transparent and robust, multi-criteria analysis rating method is applied in comparison to more sophisticated ranking and pairwise comparison methods assigning weighting factors. Whereas the development of a functional C&I model, which identifies quantitative and qualitative relationships between the decision elements and their importance, will be a high priority task for future research, it is not feasible for practical application at this time.

4.3 C&I Set

The preliminary Generic Set of C&I is designed for the evaluation of sustainability of temperate forest management internationally. It is mostly based on the North American Test set of C&I, which is the most developed and tested C&I Set for temperate forests internationally. Although the scientific justification of a C&I Set is problematic due to the holistic nature of sustainability and the limited scientific understanding of the complex multiple dimensions of forests, the North American Test set provides some confidence based on the most advanced testing procedures applied and the comprehensive documentation provided for each principle, criterion and indicator.

Although the presented set can be considered optimal and minimal at this point of time, further refinement will take place in the future based on improved scientific understanding of sustainable forest management and the experiences gained from field testing and implementation. Incorporating field experience based on practical C&I implementation in a variety of FMUs under different forest conditions internationally will be the key component for further optimization of the Generic Set of C&I for SFM at the local FMU level in the future.

4.4 C&I field testing

Indicator measurement requires the selection or development of suitable verifiers and norms. Verifiers are indicator measurement methods and are selected within the specific regional or local context in order to increase the practicability of C&I applications. Their selection also depends on data availability at the FMU under investigation. The justification of verifiers selected is difficult due to varying suitability under different conditions and uncertainty concerning the relationship between verifiers and corresponding indicators. Norms are indicator measurement units and define a range of threshold values based on expert knowledge. Their justification is provided if the regional or local forest management standards used for their development are widely accepted by the scientific community, forest

managers and forest stakeholders. Norms are formulated not only by science, but also in the context of changing forest values and demands of society.

The C&I field testing at the Haliburton Forest has been applying a variety of verifiers for indicator measurement, based on generally accepted field methods and data availability. However, the first major obstacle for successful C&I implementation is the considerable resources required for complete data collection covering the entire set of C&I. The Haliburton Forest has been employing a multi-purpose forest management concept and conducting research on a variety of components of sustainable forestry for over a decade. It already has comprehensive databases on sustainable forest management variables, complemented by a variety of additional studies within this research project. This is not a common scenario for a regular FMU internationally. The data collection within the application of a C&I System requires enormous resources and implies significant costs.

The second problem is the quality and reliability of the data collected. Because the data collection methods and the representativeness of data collection vary widely, the scientific reliability of indicator measurement results is problematic. For this reason, only three measurement units are defined for each indicator norm, allowing a basic but transparent and robust ranking in the form of a trend analysis.

Whereas indicators covering traditional forestry variables can be measured easily based on mostly existing data, others related to fields such as forest ecology, non-timber values and social aspects are characterized by measurement difficulties. The development of a range of generally applicable, standardized, practical and cost-efficient verifiers for indicator measurement complementing the Generic C&I Set should be given a high research priority in the future. The development of regional forest management standards, such as those developed within the FSC program will be highly supportive for the implementation of C&I internationally.

Experience gained from the field testing within the Case Study has shown the feasibility of the implementation of C&I for SFM at the local FMU level. Furthermore, the study shows that the data collection for the purpose of the C&I field testing and implementation has influenced forest management planning and operations at the Haliburton Forest, moving the FMU closer to a more sustainably managed forest.

5. Conclusions

The concept of C&I for SFM at the local FMU level is a unique achievement in forestry in conceptualizing and evaluating forests and forest management from a holistic perspective. There is still need for refinements based on further research and field experience. Further C&I testing and implementation based on comprehensive data collection is still required. The concept provides a definition of sustainability and allows the evaluation of progress towards achieving SFM, but the formulation of normative targets and decision-making based on value judgements and conflict resolution is still necessary.

An optimum state of sustainability may be identified by maximizing positive effects and minimizing negative effects and conflicts within and between all systems of forestry. It appears that perfect sustainability does not exist, only a variety of different sustainability scenarios can be identified. Finally, the definition of sustainability for forests depends on the weighting process concerning priorities between the multiple and often conflicting dimensions of forest and forest management.

This study contributes to the field of sustainable forestry by presenting a System approach towards C&I for SFM, by suggesting an optimum and minimum Generic Set of C&I for SFM at the local FMU level in temperate forests internationally, and by providing field testing

experiences based on comprehensive data collection at the highly suitable Haliburton Forest Case Study. Finally, the study also contributes to the international promotion and implementation of sustainable forestry.

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Appendix

Preliminary Generic Set of Criteria and Indicators for Sustainable Forest Management at the Local Forest Management Unit Level in Temperate Forests (modified and extended from Woodley et al. 1998a and CIFOR 1999b).

Principles	Criterion	Indicator	Source
1 Ecological integrity is maintained			NAT
	1.1 Landscape patterns are maintained		NAT
		1.1.1 Level of forest fragmentation and connectedness of forest components	NAT
		1.1.2 Road network density, type, use and location	NAT
		1.1.3 Extent to which forest management considers the protection of unique of significant landscape level features	New
	1.2 Ecosystem diversity is maintained		NAT
		1.2.1 Rate and total area of forest land (major forest types) converted to non-forest land cover	NAT
		1.2.2 Area of vegetation types and structural classes relative to the historical condition and total forest area	NAT
		1.2.3 Representation of selected key and sensitive guilds occur in the community guild structure	NAT
	1.3 Ecosystem function is maintained		NAT
		1.3.1 Area and representativeness of protected areas for enabling natural processes as well as habitat and species conservation	CIFOR (mod.)
		1.3.2 Ecologically sensitive areas are protected (e.g. buffer zones along water courses)	NAT
		1.3.3 Coarse woody debris and snags retained at functional levels	NAT
		1.3.4 Area and severity of natural disturbances by storm, insects, wildfire etc. (mod.)	NAT
	1.4 Native species diversity is maintained		NAT
		1.4.1 Populations of indigenous species are likely to persist	NAT
		1.4.2 Number of known indigenous species classified as extinct, extirpated, endangered, threatened or vulnerable relative to the total number of indigenous species	NAT (mod.)
		1.4.3 Species protection and restoration programs for endangered, threatened, vulnerable or rare species	CIFOR (mod.)
	1.5 Genetic diversity is maintained		NAT
		1.5.1 Population sizes and reproductive success are adequate to maintain levels of genetic diversity	NAT
		1.5.2 Use of scientifically-based seed transfer rules and seed orchard zones in planting native species	NAT

Principles	Criterion	Indicator		Source
		1.5.3	Management does not significantly change gene frequencies	NAT
	1.6	Physical environmental factors		NAT
		1.6.1	Area and percentage of harvested area with degraded soil quality (e.g. soil compaction, displacement, erosion, puddling and loss of organic matter)	NAT (mod.)
		1.6.2	There is no significant change in the quality and quantity of water from the forest catchment	CIFOR
	1.7	Incidence of disturbance and stress		NAT
		1.7.1	Area and severity of occurrence of exotic species detrimental to forest condition	NAT
		1.7.2	Pollutant levels (emissions) and chemical contamination (e.g. herbicides and pesticides) in the ecosystem	NAT (mod.)
2	Yield and quality of goods and services are sustainable			NAT
	2.1	Forest management provides for sustainability of goods and services		NAT
		2.1.1	Land base available for timber production	NAT (mod.)
		2.1.2	Mean annual increment for forest type and age class	NAT
		2.1.3	Annual and periodic removals calculated by area and/or volume prescribed	NAT
		2.1.4	Silvicultural systems prescribed are appropriate to forest type, production of desired products and condition, and assure forest establishment, composition and growth	NAT
		2.1.5	Harvesting systems and equipment are prescribed to match forest conditions in order to reduce impact on wildlife, soil productivity, residual stand conditions and water quality and quantity	NAT
		2.1.6	Recreational use management provides recreational services while minimizing impact on wildlife and environment	New
		2.1.7	Wildlife management provides hunting opportunities and is ecologically oriented and sustainable	New
	2.2	Forest management is socially efficient		NAT
		2.2.1	Availability and use of recreational opportunities are maintained and other non-timber values are provided	NAT (mod.)
		2.2.2	Economic importance of non-timber products and services	NAT (mod.)
		2.2.3	Existence of economic rents (total management revenues exceed management costs)	NAT (mod.)

Principles	Criterion	Indicator	Source
3 Society accepts responsibility for sustainability			NAT
	3.1 Forest management provides ongoing access to the resource		NAT
		3.1.1 Access to forest resources is fair and secure	NAT (mod.)
		3.1.2 Ownership and use rights and responsibilities to resources (inter- and intra-generational) are clear and respect pre-existing claims	NAT
	3.2 Concerned stakeholders have a right to participate in open and meaningful public participation processes in order to influence management		NAT
		3.2.1 The process should be inclusive with all interests represented	NAT
		3.2.2 Stakeholders have detailed and meaningful reciprocal background information necessary to provide quality input into the public participation process	NAT
		3.2.3 Management staff and stakeholders should recognize and respect the interests and rights of each other	NAT
		3.2.4 The decision-making process is transparent and considers the interests and values of stakeholders	NAT (mod.)
		3.2.5 Extent to which forest management considers the protection of unique or significant sites of social, cultural, spiritual or scientific importance	New
	3.3 Recognition and respect for Aboriginal roles in sustainable forest management (Aboriginal rights, Treaty rights and aboriginal values)		NAT
		3.3.1 Extend to which forest management considers and meets legal obligations concerning duly established Aboriginal and treat rights	NAT
		3.3.2 Extent of Aboriginal participation in forest-based opportunities	NAT (mod.)
		3.3.3 Extent to which forest management considers the protection of unique or significant Aboriginal social, cultural or spiritual sites	NAT (mod.)
		3.3.4 Area of land available for subsistence purposes	NAT
	3.4 There is equitable access to and distribution of economic rents		NAT
		3.4.1 Economic importance of FMU for local communities	NAT (mod.)
		3.4.2 Employment of local population at FMU	NAT (mod.)
		3.4.3 Distribution of rent capture	NAT (mod.)
		3.4.4 Mechanisms exist for sharing economic benefits	NAT
		3.4.5 Wages and other benefits conform to national and/or ILO standards	NAT

Principles	Criterion	Indicator	Source
	3.5	Forest based human health issues	NAT
		3.5.1 Forestry employers follow ILO working and safety conditions and take responsibility for forest-related health risks of workers	NAT
		3.5.2 Forest management cooperates with public health authorities concerning forest-related illnesses	NAT (mod.)
4	Enabling conditions for sustainable forest management		NAT
	4.1	Policy, planning and institutional framework are conductive to sustainable forest management	NAT
		4.1.1 Forest management considers and meets legal forestry requirements and standards	New
		4.1.2 There is sustained and adequate funding and staff for forest management	NAT
		4.1.3 Policy and planning are based on recent and accurate information	NAT
		4.1.4 Objectives are clearly stated concerning major functional forest areas	NAT
		4.1.5 Effective instruments for inter-institutional coordination on land use and forest management exists	NAT
		4.1.6 Institutions responsible for research are adequately funded and staffed	NAT
	4.2	The management plan is implemented and effective in moving toward stated goals	NAT
		4.2.1 Continuous inventories established and measured regularly	NAT
		4.2.2 Documentation and records of all forest management activities are kept in a form that makes monitoring possible	NAT
		4.2.3 Actual vs. planned performance is measured and recorded	NAT
		4.2.4 An effective monitoring and control system audits management's conformity with planning	NAT

Implicit and Explicit Paradoxes in Managing Certified Forests in the United States

Theodore E. Howard

Department of Natural Resources, University of New Hampshire
Durham, NH, USA

Abstract

Because sustainable forestry is a complex endeavor, paradoxes exist in the certification criteria and indicators. There are different ways to establish the sustainability horizon and alternative harvest profiles that, although sustainable, do not meet specific criteria. Silvicultural criteria also conflict. The application of historic range of variation information must confront issues of time and spatial scales as well as how much human disturbance is natural. Defining 'local' in the bioregional context is important for addressing socio-economic criteria. The paradoxes are natural and our abilities to deal with them will improve as we gain experience in the certification process.

Keywords: harvest rate, range of variation, bioregionalism, certification, sustainable forest management, Criteria and Indicators

Introduction

Not only is sustainable forestry a complex endeavor, there are multiple perspectives on what sustainable forestry is. The spectrum of definitions ranges from extreme anthropocentric utilitarianism to extreme biocentrism (Gale and Cordray 1994). Given the complexity of the task and the variety of viewpoints, we should not be surprised by contradictions within the criteria and indicators that foresters must apply at the forest management unit level. These internal inconsistencies or paradoxes are both explicit and implicit in nature.

In an explicit paradox, we can juxtapose two criteria and immediately envision the potential for conflict. A criterion may call for a particular practice that directly constrains the implementation of another criterion. In an implicit paradox, the incongruities are less obvious, but perhaps more important because they hide value judgments and imperfect information within

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seemingly objective criteria. For example, criteria expressing preferences for 'local processing' depend on the definition of 'local' and may have adverse effects on a forest's economic viability.

The objective of this paper is to discuss some of these explicit and implicit paradoxes. For the most part, I will use examples from the Forest Stewardship Council (FSC) and from one of its accredited certifying bodies, SmartWood. Their role as sources for this paper does not imply any special favor or criticism. They are simply the organizations with which I am most familiar. FSC is also the most important third-party certification body in the USA. As of 29 February 2000, 1.6 million hectares of USA forestland were FSC-certified (FSC 2000).

In addition to FSC, there are other sustainable forestry programs in North America. These include the International Standards Organization's ISO 14 001, the Canadian Standards Association's Canada's National Sustainable Forest Management System Standard (CAN/CSA Z809-96) and the Sustainable Forestry Initiative (SFI) of the American Forest & Paper Association (AF&PA), the major trade association of the USA forest products industry. AF&PA's member companies own and manage over 20 million hectares of forestland within the framework of SFI. However, unlike FSC's third-party assessment approach, SFI is largely a second-party certification process (i.e. all members adhere to the association's standards). Recently, SFI has added third-party audits and at least four major forest products companies within its membership are participating in that new effort.

While I am not as familiar with these other systems, I would not be surprised to find contradictions in them, too. It may well be the very nature of forest management that such paradoxes exist. Davis et al. (2001) describe two types of management problems, type A and type B. Type A problems have clearly defined goals, objectives, and constraints and employ objective criteria for selecting an optimum solution. Operational planning using linear programming fits the type A situation. Type B problems, on the other hand, have multiple and, often, conflicting goals and objectives and subjective judgment is employed to select the preferred course of action.

Sustainable forest management is the classic type B problem. There are many views of what we should be sustaining and how we should do it. As a consequence, paradoxes naturally arise in the criteria and indicators that foresters apply at the management unit level.

Explicit Paradoxes

Within FSC's and SmartWood's criteria and indicators are several examples of potential contradictions. This paper will focus on just two examples: (1) the rate of harvest criterion; and (2) silvicultural prescriptions.

Rate of harvest

One of the key criteria for sustaining forest production is the rate of harvest of forest products that can be permanently sustained. The managing forester must determine over what time period the harvesting rate should be measured and how to determine permanently sustainable levels.

The time issue has two parts. The first is a minor consideration of annual versus periodic allowable cut. SmartWood criterion 3.4 calls for the determination of an annual allowable cut:

3.4 Annual allowable cut (AAC), by area or volume, has been set or based on conservative and well-documented estimates of growth and yield, and ensuring that the rate of harvest does not exceed sustainable levels (SmartWood 2000).

An annual allowable harvest is really only meaningful for larger ownerships that can actually support yearly operations. However, even on these forests, strategic planning is likely done on a larger increment of time such as a decade. SmartWood's criterion 4.1 softens the annual allowable cut criterion by providing for 'other calculations'. Thus, there appears to be flexibility in the interpretation of this criterion to reflect actual practice.

The second issue is the determination of the time horizon that ensures permanence. This time horizon is also connected to how to determine permanently sustainable harvest levels. How long is long enough to be sure the level is sustainable? In management planning, we typically set a planning horizon and use simulation or optimization models to generate different time profiles of harvest volumes and then implement the harvest schedule that best meets the organization's goals. In these models we can set ending conditions that we hope will ensure future sustainability. For example, when the forester employs an area control approach to regulating the forest, regulation will be achieved within one rotation. If the regulated structure is thereafter maintained, we can be reasonably certain the harvest level can be sustained. Other, non-regulated, ending conditions are also possible, but the forester must specify when those conditions will be attained. Is 120 years a sufficient horizon for sustainability or is a longer period needed to be sure that the harvest level is truly sustainable? That the criteria and indicators do not provide any clear guidance reflects the reality that the sustainability horizon will vary with each management situation.

Once the sustainability horizon has been established, the forester must determine the level of harvest that can be permanently sustained. The forester will use measures of growth and yield to help determine the permanently sustainable level. But growth and yield are only two factors for setting harvest levels. The initial age-class distribution of timber inventory and the structure of the target sustainable forest are also important. At this critical juncture, criteria developed for the northeastern USA are inappropriately specific.

> *An allowable cut has been derived based on well-documented estimates of growth and yield to provide* non-declining sustained yield *of forest products and this target is being followed in harvest planning (emphasis added) (SmartWood 1997).*

The paradox in this criterion is that the requirement for non-declining yield may impede other goals of sustainable forest management. If we have over-mature unmanaged stands, their removal may result in near-term harvest levels that cannot be sustained in the long-term when those tracts are replaced with new, managed stands. Thus, the criterion may exclude transitions to age-class structures that may actually be preferred on ecological, as well as social and economic grounds.

Furthermore, in the transition period between today's existing forest and the future's target forest, it may be necessary to remove timber at a rate greater than the pre-determined level of sustainable harvest. If the forester applies area control methods to an unregulated forest, the harvest flows during the transition period prior to regulation may be very erratic. If the initial distribution of the age-class inventory is skewed towards more mature classes, the near-term harvest flows will be above the long-term sustained yield established for the regulated forest. Figure 1 shows, for an example forest managed to a sustainability horizon of 120 years, that both the optimized and non-optimized approaches to area control have higher levels of near-term harvests than the level specified by the non-declining even-flow alternative. The area control alternatives, once regulated, are sustainable to the sustainability horizon, but at a somewhat lower level than that of the non-declining even-flow method. Thus, we have three alternatives that are sustainable, but with very different near-term harvest schedules.

The smooth flows of timber that are eventually accomplished with a regulated forest are not necessary conditions for sustainability. Foresters managing large and small forests can also adopt management strategies that harvest *stand* growth without regard to smoothing the

harvest flows from the entire forest over time. A forest management plan that is based on the aggregation of such stand management decisions without regard to forest-level smoothing can be perfectly sustainable, although the time profile of harvest flows may be quite variable (Figure 1).

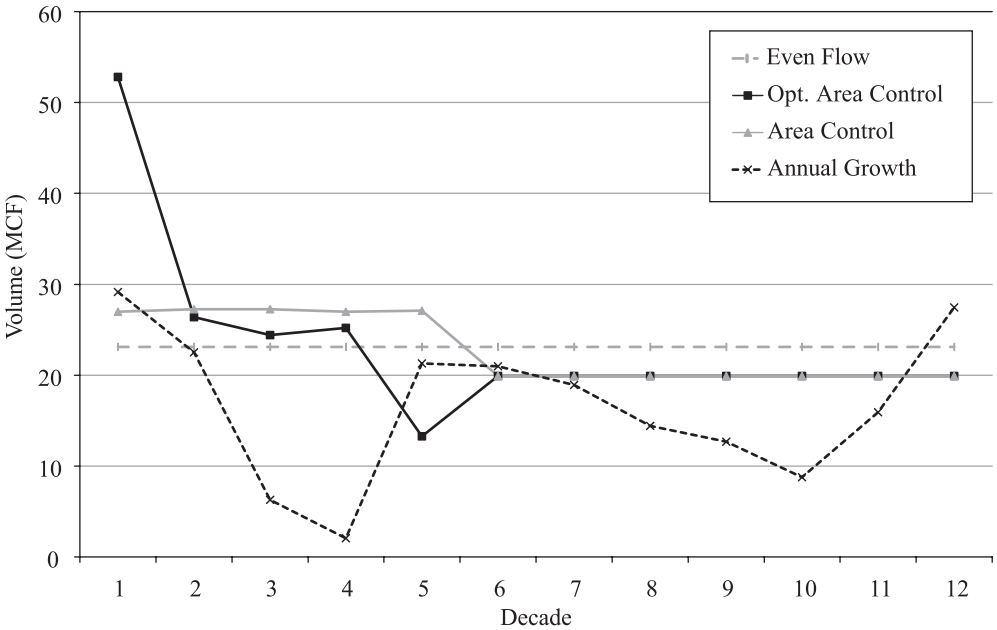

Figure 1. Volume flows by decade for alternative sustainable harvest schedules.

SmartWood's non-declining sustained yield criterion is not really useful to owners of smaller forests who are not concerned with the *continuity* of volumes, income, or other outcomes of management. The non-declining language is probably linked to US national forest policies that dictate non-declining even-flow harvests. Originally adopted to prevent rapid liquidation of publicly owned old growth timber in the western USA, a non-declining harvest level criterion does not fit most conditions of 21st century forestry and could impede sustainable forestry.

Silvicultural prescriptions

A second example of an explicit paradox can be found in the section on sustaining forest production and resource quality in the Northeast SmartWood Guidelines for the Assessment of Natural Forest Management (SmartWood 1997).

4.3 Management strategies prevent over harvesting of individual tree species.
4.4 Management strategies emphasize improving long-term stand quality.
4.5 Management addresses the restoration of degraded or low quality forest stands.

In many forest situations, we know that, due to past management practices and natural forces, the forester may be confronted with an overabundance of less desirable species. In the northeastern USA, red maple (*Acer rubrum*), a species of relatively low market value, is

claiming an increasing share of the forest inventory. If our goal is to improve and restore forest stands, the silvicultural prescription would emphasize over-harvesting red maple and other less wanted species in favor of more desirable species such as sugar maple (*Acer saccharinum*) or yellow birch (*Betula alleghaniensis*). Therefore, to meet criteria 4.4 and 4.5, the forester may need to violate criterion 4.3.

Implicit Paradoxes

Implicit paradoxes are subtle and foresters may not be as aware of the implications of these potential contradictions. To illustrate the importance of implicit paradoxes, the following sections address the concepts of 'natural' forest management and 'local processing'.

Natural forest management

Certification criteria and indicators promote *natural* forest management. To implement natural forest management requires an assessment of what is natural. One of the important indicators of whether current and future management is natural is to compare the current and expected conditions with those of the past. The historic range of variation (HRV) serves as a benchmark to which comparisons can be made.

Management decisions that produce outcomes and conditions within the historic range of variation may be preferred over outcomes that are not within that range. To establish the HRV for a given situation, foresters must have a reliable time-series of observations from which to construct the historical record as well as a reliable prediction about the outcome of future management that will be compared to that historical record.

The HRV can be represented as a graph of the relevant data with the indicator variable for the criterion on the vertical axis and an appropriate time scale on the horizontal axis (Figure 2). The observations are plotted on a grid that shows the average value of the observations and one or two standard deviations above and below the average. To use the graph, foresters must evaluate the pattern and trends as well as the average conditions and upper and lower bounds. In Figure 2, the indicator has rarely ventured outside of either the upper or lower bounds of one or two standard deviations from the average. However, the trend in the indicator is clear and most recent observations are decidedly below the long-term average.

HRV raises issues of spatial and time scales, and of the appropriateness of human disturbance. The spatial scale paradox is that the historic data are often collected across a large spatial scale so that, on average, the range of variation is more limited than it is on the local scale (Figure 3). On the local scale, ecological parameters such as the percentage of old-growth forest can range from 0% to 100% while on the regional scale, the percentage of old-growth forest may only range from 25% to 75%. Thus, applying regional (large-scale) information to more site-specific (small-scale) management may produce 'unnatural' results.

The time scale over which the historic range of variation is measured introduces additional implicit paradoxes. Some definitions of the historic range of natural variation in North America put a premier value on conditions that existed prior to European settlement. For convenience, I will refer to such perspectives as *holistic*. The holistic critique of disturbances that began with European settlement is that those disturbances were born of a world-view that held humanity separate from nature, so-called *dualism*. The critique argues that the dualist approach should be abandoned in favor of a holistic approach that recognizes humanity as part of nature. However, by defining natural conditions in terms of a pre-European metric,

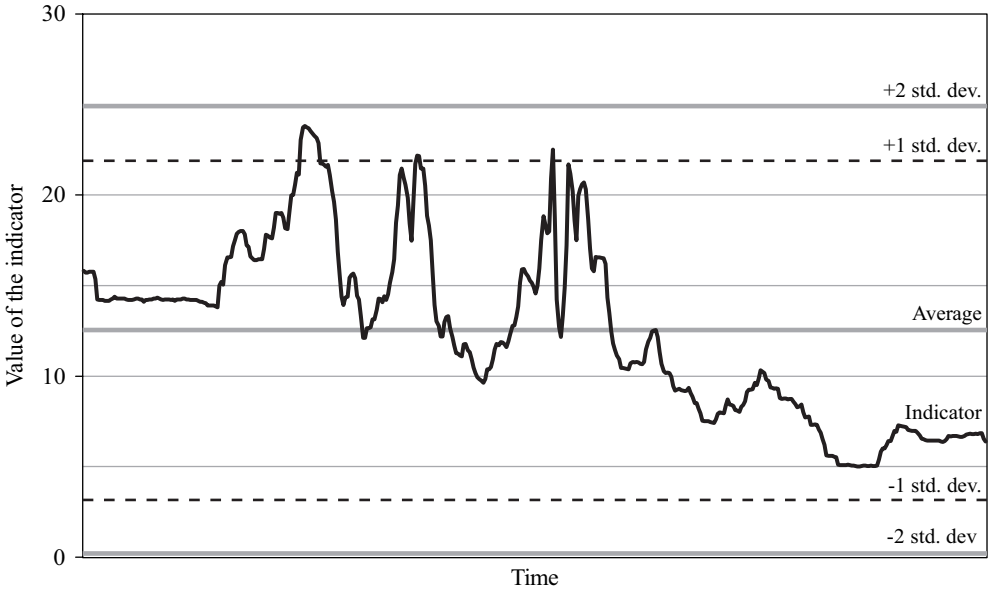

Figure 2. Example of historic range of natural variation for a sustainability indicator.

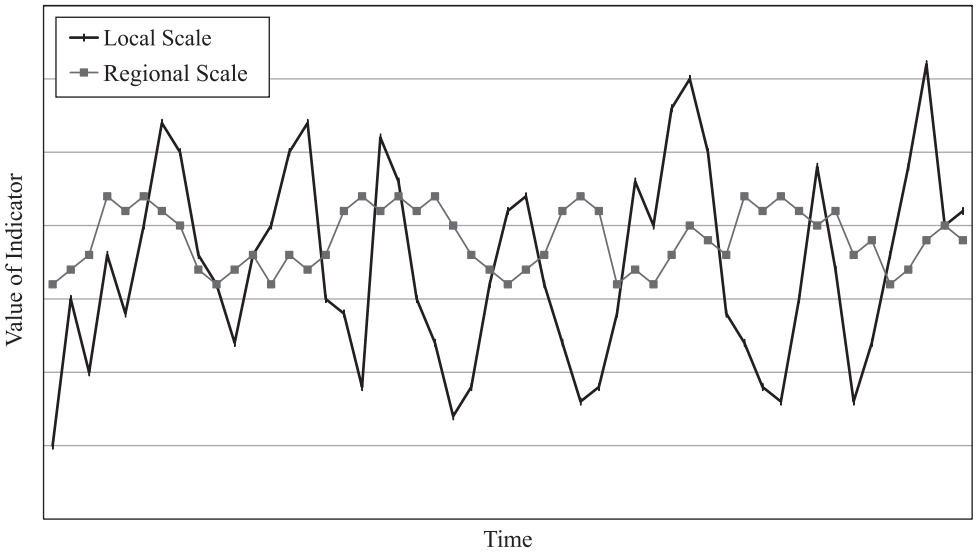

Figure 3. Historic range of natural variation at local and regional scales.

holists must, paradoxically, adopt the dualist philosophy that actions of the Europeans in North America were and are, in fact, separate from nature.

Few would argue that a return to pre-European conditions is either feasible or desirable. However, there is a tendency to define natural as being free from western industrial disturbances. The disturbances caused by native populations are seen as natural because there is the widely held view that the indigenous people lived in harmony with nature and that their interactions with nature were benign. The paradox in that view is that native populations also lived at the mercy of

nature. If drought was extensive, death and population reductions were the natural consequences. Furthermore, their activities were not always benign. Native Americans were, in fact, knowledgeable land managers and made particularly heavy use of fire (Williams 1989). Although not a North American example, the Maori of New Zealand's South Island were also once prolific users of fire for wildlife management purposes. Excessive burning over a long time period led to the destruction of large areas of native beech forest, which were replaced by tussock grass communities that today cover thousands of hectares.

There is another time dimension to the criteria and indicators that seek to maintain natural forest conditions: the future. The paradox is that we are using the paleoecological record (the past), to judge existing management activities and to formulate plans (the present) that we hope will replicate the past in the future. Yet, how can we be sure that macro conditions that we cannot control and that influence the success or failure of our management will be as expected? Should we re-create the past if anthropogenic atmospheric pollution warms the global climate outside of the range historic variation? Will the forest that we have re-created in the image of the historical forest be more vulnerable to environmental disaster if the worst-case predictions are realized? Would we be better off simply maintaining the kinds of forests we have now? I do not know the answer, but surely we should be thinking about this rather than merely accepting that the forests we have today are automatically inferior to those of the distant past.

For that matter, can we really re-create the past? Global trade, for example, is accelerating the pace of dispersion of unwanted plant and animal pests. In this century, we have lost the once dominant American chestnut (*Castanea dentata*) from the entire eastern USA due to an imported disease. Dutch elm disease has largely eliminated American elm (*Ulmus americana*) and the hemlock woolly adelgid threatens eastern hemlock (*Tsuga canadensis*) from New York to the Canadian border. Gypsy moth, another introduced pest, has had profound influences on the structure of eastern USA forests. In the face of these and other future attacks, does 'natural' becomes an elusive goal?

Local processing

The FSC principles and criteria for sustainable forest management encompass a broad range of social and cultural issues. Many of the criteria expect the managing forester to consider the impact of management on local communities. The goals associated with these criteria are to provide higher levels of economic and social benefits to natural resource dependent communities and to prevent exploitation of those communities. One of these criteria clearly favors local processing of harvested timber. Forest management and marketing operations should encourage the optimal use and local processing of the forest's diversity of products (FSC 1999).

The local processing preferences were developed partly to avoid situations in which an exporting nation received little or no benefits. Wood colonies were to be avoided, and the local processing criteria seem particularly directed toward developing nations, where deforestation and over-exploitation of forests are well-documented problems.

Given the local processing criterion as a basis for argument, some advocacy groups have opposed certification of specific forest owners in the northeastern USA because those owners exported unprocessed logs. This creates an interesting paradox. If the manager strictly interprets 'local processing', there may be conflicts with economic viability criteria. The log export market in the northeastern USA typically offers higher prices for logs than does the domestic market. These higher revenues may be the critical marginal revenue increments necessary to maintain long-term forest management and even to protect the forest from conversion to non-forest uses with higher economic rents.

But the export–local market issue is even more complicated. The northeastern USA forest is the wood source for dozens of wood products manufacturing facilities in southern Québec, Canada. Although eastern white pine (*Pinus strobus*) is not the most important species to be exported from the northeastern USA to Québec, it does illustrate the transboundary flows of wood. Since the early 1990s, the export volume has been increasing so that by 1997 nearly 700 000 m^3 of unprocessed pine logs flowed into the province from various sources in the USA (Figure 4). Similar patterns exist for eastern red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*). Approximately 14% of the annual harvest from the four border states of Maine, New Hampshire, Vermont, and New York is exported to Canada, mostly to Québec (Irland 1999). The mills that import these unprocessed logs are highly dependent upon this flow and several mills have long-standing relationships with log suppliers and landowners in the USA. Many of these mills are located within 100 kilometers of the international boundary between the USA and Canada and are often closer to the forest source than competing mills in the USA. In some cases, Canadian logging companies use a Canadian labor force to harvest the American timber.

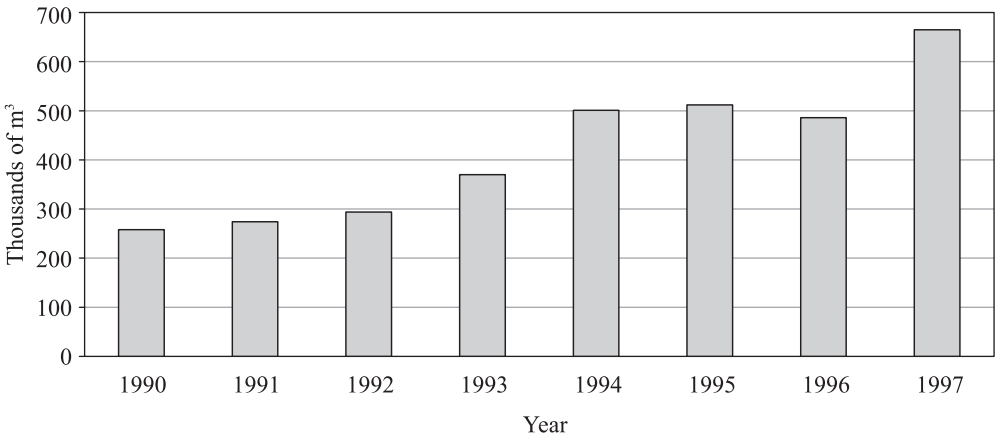

Figure 4. Eastern white pine log exports from the USA to Québec, Canada.

The border regions of southern Québec and the northern fringe of the northeastern USA share a common ecosystem and interact economically and socially. In this context, is the nearby Canadian mill 'local' or not? Some of the region's environmental groups have suggested that these exports are not acceptable and have proposed changes to public policies that would limit these export flows (Northeast Natural Resource Center 1995).

In assessing the criteria related to local processing, how would we judge a USA forest enterprise that exports 60% or more of its harvest from its forests located adjacent to southern Québec, to buyers in southern Québec? Does this constitute local processing? Some opponents of forest management argue that it is not local processing, but, paradoxically, these are often the same people who favor environmental protection across political boundaries on the basis that the ecosystem is the appropriate jurisdiction. They acknowledge political boundaries when it is convenient to their position. I would rather employ a bioregional approach in judging the degree of local processing.

In bioregionalism, the ecosystem is the preferred unit of analysis and it explicitly integrates human communities as part of those ecosystems. The sustainability of a bioregion must

encompass, not only the sustainability of the resource base, but must combine community sustainability beyond its economic dimensions to include social and cultural sustainability of resource-dependent communities (Howard and Straussfogel 1999). Thus, in a bioregional framework, log exports are not automatically grounds for non-certification. Instead, we recognize that ecosystems, economies, and cultures, may transcend international boundaries. In our present example, if the managing forester adopts a bioregional view, then the foreign mills in Québec are, paradoxically, local.

Conclusion

None of the above paradoxes, whether they are explicit or implicit, can be resolved easily. Perhaps they cannot be resolved at all. What is important is that the managing forester, in conducting his or her responsibilities, must be mindful of the conflicts and tensions embedded in certification criteria and indicators. They will need to clearly communicate to owners, accrediting bodies, and stakeholder communities how they have balanced these tensions. The owners, accrediting bodies, and stakeholders, each with their own interpretations of 'sustainable forestry', will judge how well the balance has been achieved.

Just as the forest itself is dynamic, so too is the certification process. I am confident that the process will continue to evolve as forest science advances and as we gain experience in applying the criteria and indicators in practical situations.

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Concept of Sustainable Forest Management Evaluation in the Forestry Planning at the Forest Management Unit Level: Some Experiences, Problems and Suggestions from Slovenian Forestry

Andrej Boncina

University of Ljubljana, Department of Forestry and Renewable Forest Resources, Ljubljana, Slovenia

Abstract

The importance of sustainable forest management (SFM) in the forest planning procedure is explained, with the focus on three major points: (1) considering the sustainability principles in the forestry planning; (2) defining indicators of SFM at the forest management unit (FMU) level; and (3) defining reference values and some dilemmas of their use. The sustainability principles have to be integrated in all planning phases and respected in the implementation of planned activities. SFM evaluation is an important part of forestry planning. For SFM evaluation, two approaches are of equal importance, as they supplement each other: (1) comparison of actual and reference indicator values; and (2) monitoring of forest development and analyses of previous forest management. SFM indicators can be divided into three groups: (1) indicators of ecosystem condition; (2) treatment indicators; and (3) indicators of economic, social and organisational conditions. The efficiency of SFM evaluation depends on many facts: how reference values are determined; how they are understood; and how they will be applied in the decision making. Reference values can be defined either by adequate researches or through experiences in the adapted forest management. Reference values have to be adapted to site conditions, stand structure and composition, and above all, to management goals. They have to be understood as frame values.

Key words: sustainable forest management, indicators, reference values, forestry planning, Slovenia

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1. Introduction

The concept of sustainability reflects human relations toward nature and toward the use of renewable natural resources. It probably derives from forest use, but it is nowadays used in a broader sense, representing a possible alternative in the development of society. The German term 'Nachhaltigkeit' was first used by Carlowitz (1713), although the roots of sustainable forest use are much older. They can be found in Ancient Greece and Rome, in the early Middle Ages close to Mediterranean towns, later in Central Europe in the vicinity of larger settlements and mines (Anko 1993; Bernasconi 1996; Boncina 1998; Hughes 1981; Johann 1994a; Johann 1994b; Mayer 1994; Schuler 1981). Historically, the content of forest sustainability has changed constantly. In the beginning it was limited to wood (sustained yield, sustained forest area), broadened later to sustainability of some forest functions (e.g. protection function and sustainable use of water resources), still later to sustaining forest productivity, then to sustainability of all forest functions. Recently, the most accentuated demand is to sustain the forest as a functional system (Christensen et al. 1996; Franklin 1993; 1994; Kaufmann et al. 1994). Due to global problems such as biodiversity loss, forest fragmentation, deforestation, pollution, scarce energy supplies, and larger demands of the society, the ecological and the social components of SFM have gained importance. The economic aspect is still of great importance for a sustainable society development; wood as a renewable natural resource contributes greatly to solving ecological problems (energy, pollution, global warming) and prevents depopulation of the countryside.

Forestry planning has been a traditional tool for ensuring forest sustainability; in the beginning only the methods enabling sustained yield were cherished, although recently concepts of multiple functional forestry and biodiversity conservation have become more and more important. Therefore, many problems and dilemmas have arised regarding assessment of SFM on different spatial levels – from stand and landscape to regional or even global level. The assessment on the particular level is usually based on SFM standards – principles, criteria, indicators, and their reference values. SFM in Slovenia has had quite a long and rich tradition. However, SFM is 'a never ending story'. New content and understanding of SFM as well as new problems regarding SFM demands a modified concept of SFM evaluation in the forestry planning. The SFM evaluation in forestry plans is still not completely defined, and sometimes even underestimated. The key questions are: (1) the evaluation of SFM criteria in forestry planning on different levels, using indicators and their reference values; and (2) ensuring the use of the principles of sustainability in the forestry praxis at all. The aim of this paper is to describe the way of respecting SFM principles in the process of forestry planning at the level of the FMU, and especially to determine the procedure of SFM evaluation, using indicators and their reference values. SFM depends on natural, economic and social conditions; therefore some characteristics of Slovenian forestry are described in the second chapter. In the third chapter, the SFM principles in the planning process are defined. Major attention is given to evaluation of SFM, based on indicators and their reference values. Some basic SFM indicators at the level of FMU are defined and some problems of their reference values are described. Two cases of indicators are analysed in detail. The dilemmas, suggestions and additional approach of SFM assessment are also discussed.

2. Some Characteristics of Slovenian Forestry and Forestry Planning Regarding the Concept of SFM

In forestry practice huge differences exist among different countries. Due to their economic, social and natural conditions, each country has developed some special characteristics

regarding forests and forestry. To understand SFM in Slovenia, the following facts are important:

- The clear-cutting system as a management method has been prohibited in Slovenia since 1949.
- Nature conservation has traditionally been included as an important and constituent part of forestry. More than 100 years ago, foresters were the first to protect virgin forest remnants in Slovenia (Hufnagl 1892). At the same time Hufnagl introduced the autochthonous selection silviculture system. A few years later, Schollmayer (1906) improved his work by applying the concept of adaptive forest management. Both of them strongly influenced the next generations of foresters in Slovenia. The concept of nature-based silviculture was especially improved by Mlinsek (1968). Nowadays, nature conservationists are included in the process of forest planning.
- Since the 1950s and 1960s, forest plans have been introduced in all Slovenian forests irrespective of their ownership. As a consequence, all forests have been covered by plans and included into the forestry information system. The Slovenian Forest Service (SFS) is responsible for forestry planning and forest monitoring.
- In the 1960s, phytocoenology was broadly introduced into Slovenian forestry; almost half of the total forest area was mapped using Braun-Blanquet approach at a spatial scale of 1:10 000. The maps represent a basis for forest classification, basing on site conditions.
- In the 1970s, the concept of multiple forest use respecting public and private demands was put forward. The forest inventory was expanded to evaluation of different social and ecological forest functions (e.g. habitats, recreation, natural heritage, education, health, etc.).
- SFM and the concept of multiple forest-use are strongly regulated by the Forest Act of 1993. Property rights are regulated and even limited by strong emphasis of public interest. For example, free access and free movement is allowed in all forests. In addition, maximum allowable cut taking into account forest productive capacity is defined by forest plans. The use of chemicals and grazing is prohibited.
- Some trends in Slovenia are totally opposite to those going on in much of the rest of the world. For example, the forest area is still increasing, encompassing now around 55% of total area; at the same time, the population is decreasing.
- Small-scale forest ownership prevails, the average size of a private forest property is around 2.7 ha, comprising on average 2.4 spatially dispersed allotments. Social conditions have been strongly changed and practically none of the owners of small forests are directly economically dependent on incomes deriving from their forests (Winkler and Krajcic 1997). Therefore forest owners are less interested in working in their forests, the amount of harvested timber is decreasing resulting in the lower portion of forestry sector in GDP. It is possible that the consequences of these facts favour forest biodiversity, but they do not by any means contribute to a sustainable development of society.

The main task of forest planning is to organise multiple forest use respecting forest owners' demands, public interest and natural conditions. Foresters have to ensure the intersection of three basic components of SFM – the ecological, economic and social components. It seems that the concept of SFM is realised if the management is multiple use, ensuring different forest services and goods, and if it is nature based, sustaining forests as functional systems (Figure 1). Such defining of SFM is very declarative; in reality it should be somehow assessed and made more concrete (Sections 4 and 5).

The concept of SFM is relevant at different spatial scales – from a tree to stand, to landscape, to region and to country. Thus it is very important and useful for the forestry planning in Slovenia to be organised at different spatial levels:

- National level: the forest development program was passed by the National Parliament defining above all the national forestry policy and main concepts of forestry practice.
- Regional level: each region encompasses approximately 100 000 ha of forests. Regional forest plans are revised every ten years.
- FMU level: it can be regarded as a landscape level encompassing a forest area of 2000–6000 ha.
- Detailed level: plans are made on stand level, encompassing a forest area of a few tens of hectares.

There are 253 FMUs in Slovenia. Forests are classified according to site conditions into forest types as important planning units, these being further divided into sub-compartments. A sub-compartment is the smallest relatively sustained planning unit with an average area of 14 ha. They are further divided into particular stands, which are mapped at a scale of 1:10 000 (Figure 2). The level of FMU will be considered in the following chapters.

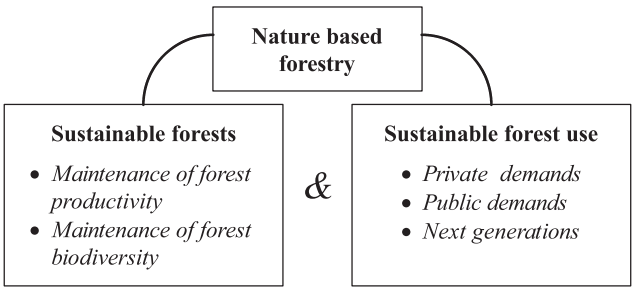

Figure 1. Sustainable forest management (SFM) includes tree main principles of contemporary forestry: sustaining forests, multiple forest use and nature based forestry (Boncina 1998).

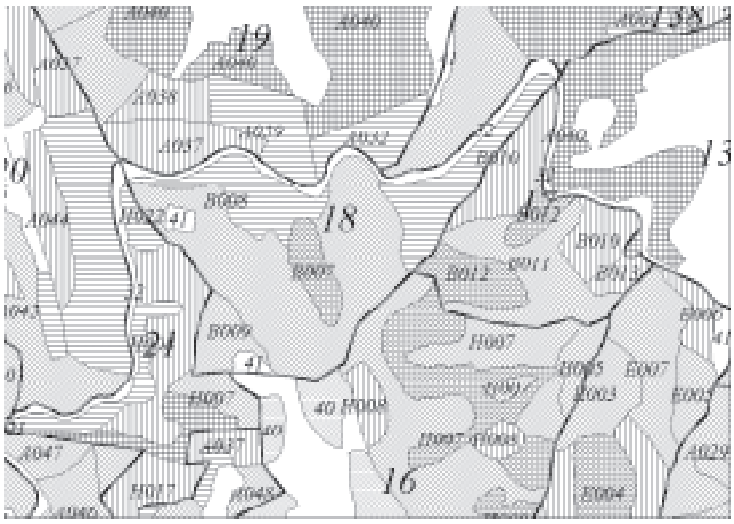

Figure 2. Map of forest stands, produced by the SFS (Forestry unit Sodrazica).

3. Planning Process and Sustainable Forest Management

The planning process can be divided into the following planning phases: (1) assessment of natural and social-economic conditions; (2) setting the management goals; (3) determing the strategies, guidelines and restrictions for (forestry) activities – this phase is later followed by implementation; and (4) monitoring, connecting all the mentioned phases into an adapted planning process based on the control.

It is very important that the principle of sustainability is incorporated into all of the mentioned phases in a practical and operative way:

1. The planning phase 'assessment of conditions' includes forest inventory and data analyses, analysis of forest development and past forestry activities, and scenario for future forest development. The SFM evaluation (see chapter 5) is a part of this planning phase, creating a starting point for a new plan, attempting to solve some of the SFM problems in the future.
2. During the planning process on the level of forestry unit forest management goals (Figure 3) have to be defined in order to determine the multiple use of forests. To respect different demands on forests and to avoid conflicts arisen by the forest use it is necessary to include all parties involved (e.g. forest owners, nature conservationists, forestry estates, local authorities, of different associations, etc.). In Slovenia, the development of the so-called participating planning (Gaspersic 1995; Bachmann 1997), involving different partners in the planning process, is an actual task for the future. At present, great emphasis is given to evaluation of forest non-timber goods and services; that has resulted in a map of forest functions, produced by the Slovenian Forest Service (Figure 4). The management goals require a suitable forest structure (Thomasius 1992) ensuring expected forest goods and services. It is defined by silviculture goals (e.g. composition, stand structure, etc.) for different forest types, respecting at the same time ecological conditions (forests sustainability!) and management goals (sustainable forest use!).
3. One of the tasks of forestry planning at the FMU level is to harmonise different forestry activities (e.g. silviculture, skidding, street construction, hunting, etc.) (Figure 3). Silvicultural measures probably present the most important impact on forest ecosystems. Success of SFM depends to a large extent on silvicultural approaches. One of them is ecosystem based sillviculture, also called 'near-to-nature silviculture', which is favoured

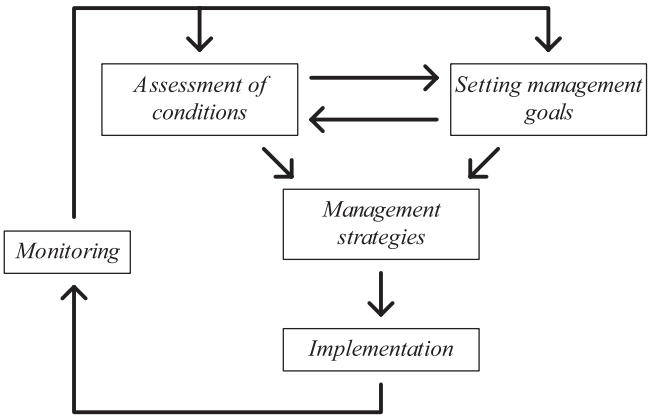

Figure 3. A simplified framework of forest management planning.

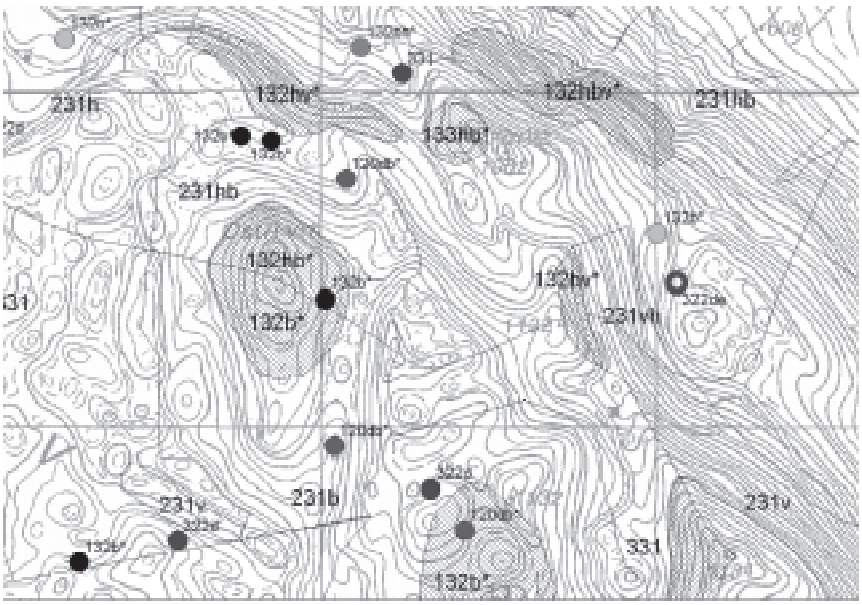

Figure 4. Map of forest functions, produced by SFS (Forestry unit Velika gora).

in Slovenia. It is characterised by natural forest regeneration, conservation of natural tree species composition and stand structure, well preserved habitats, high growing stock and high number of large trees, and a regard for the local site conditions. Forest management plans for FMUs have to determine guidelines, measures and restrictions. At the forest type level, brief silvicultural guidelines and measures are determined. Likewise, special measures regarding wildlife management, recreational services and other goods and services are proposed. Locally or even temporarily some restrictions for forestry activities are determined due to wildlife (close to bear dens, wildyard and other important animal habitats, etc.) or other functions.

4. Monitoring is an important part of adapted forest management. Its meaning for SFM is defined in chapters 4.1.2 and 5.

4. Evaluation of Sustainable Forest Management

In the planning phase ‘assessment of conditions’ two main approaches of SFM evaluation can be used:

- comparison of actual indicator values of SFM deriving from forest inventory to reference values; and
- analysis of forest development and previous forest management.

Both approaches are of equal importance for SFM evaluation, as they supplement each other.

4.1 Comparison of actual indicator values of SFM to reference values

Evaluation of SFM can be based on numerical or attributive comparison of actual indicator values and their reference values (see 4.1.2). The problem of SFM can be established in

regard to deviation between actual and reference values of chosen SFM indicators. The use of this approach implies two issues: (1) how to determine SFM indicators; and (2) how to define reference values for chosen SFM indicators.

4.1.1 Determining SFM indicators

For the SFM evaluation, parameters containing valid indication and information value are of utmost importance. They are called 'SFM indicators'. They should, if possible, be available in the forest information system, quantifiable and easy to check after a certain time period. It is expected to establish indicator actual value and previous values for a 10-year period. Selection of indicators depend on the spatial scale. Some indicators are important for all spatial levels, and others are only important for a particular scale.

Indicators can be classified in different ways (e.g. Bernasconi 1996; Gaspersic 1995). The following groups of indicators and criteria are suggested:

1. 'Indicators of ecosystem condition' (forest sustainability), where the indicators for the following SFM criteria can be included: forest area, forest biodiversity, stability, vitality in health condition, natural regeneration, productive capacity;
2. 'Treatment indicators' (indicators of sustainable forest use), where indicators of recent and past forest management and indicators of other important influences are included (e.g. silviculture measures used in the past period, cut, special measures carried out, negative influences through browsing or recreation, etc.); and
3. 'Indicators of economic, social and organisational conditions'. These can be important for SFM; however, they cannot be influenced directly by foresters (e.g. forest law).

The indicators of the second and especially of the first group are the most important for SFM evaluation at the FMU level. The system-functional approach seems to be the most appropriate for determining SFM indicators (Gaspersic 1995). Forest structure is strongly connected to the forest functioning. Different disturbances (e.g. abiotic influences, silvicultural and other forestry measures, browsing and grazing pressure, pollution, etc.) are directly or indirectly reflected in the forest structure. Forest services and goods are results of forest functioning, and therefore, are dependent on forest structure. Different parameters of forest structure especially those of a stand structure are useful as indicators that help us to assess the SFM quality at the FMU level (e.g. distribution of developmental phases, tree species composition and its alteration, etc.). The information on forest stands is an important and usually the largest part of forestry data banks presenting a basis for silvicultural decisions. At the level of FMU, forest inventory is carried out every ten years. Its main part presents an inventory of forest stands. A digitised map of stands at a scale of 1:10 000 is produced as a part of a forestry geographic information system (GIS), based on field observation of forest stands, ortophoto and other available sources (Appendix 1). At the level of particular stands many stand parameters are assessed (stand type, tree species composition, growing stock, vitality, damage, natural regeneration – abundance of samplings and saplings, tree species composition of undergrowth, quality, etc.). Some of the mentioned estimations (e.g. growing stock, tree composition) are corrected by values established through objective sampling methods (e.g. by means of permanent sampling plots) at larger spatial levels. Some stand parameters are measured only on permanent sampling plots (e.g. dead wood).

Besides forest stands other parameters of forest ecosystem are the subject of forest inventory as well. They can be evaluated either by field observation of FMU or can already be integrated into the forest information system. They can also be obtained from other organisations and institutions whose activities take place in forests (e.g. hunting

organisations, natural conservationists, water supply organisations, etc.). All relevant objects are registered and mapped (Appendix 2), representing special GIS layers of forestry information system (e.g. bear dens, location of rare and endangered species, nesting areas of particular bird species, Capercaillie leks, springs and streams, caves, special habitats, rare ecosystems, etc.). Likewise, forest locations and objects, important for recreation and other social services are registered and mapped. For the SFM evaluation at the FMU level, different non-forestry information is of importance indicating actual conditions and possible disturbances in the FMU (e.g. particular parameters of all extracted wildlife, such as weight, sex, health, age, etc.) indicating the quality of their habitats.

The same indicators can indicate different SFM criteria. For example, indicator 'proportion of developmental phases' is useful as an 'ecological' as well as a 'treatment indicator'.

It is impossible to define a final set of the most appropriate SFM indicators at the FMU level, as it is impossible to define the best indicators in advance. Selection of indicator depends on natural (site condition, stand structure), social and economic circumstances, as well as their

Table 1. Overview of some ecological SFM indicators at the FMU level.
Spatial categories: (U) FMU, (T) forest type, (SC) sub-compartment, (S) stand.

Indicators	Information sources
Health condition, vitality, level of stand damage U, T, SC, S	– field description of forest – harvest timber recording (especially sanitary cut) – permanent sampling plots – aerophotography – pollution analysis (if available)
Natural regeneration (species composition, damage, abundance) U, T, C, (S)	– field description of forest – sampling of natural regeneration – permanent sampling plots
Tree species composition and its alteration U, T	– field description of forest – permanent sampling plots – aerophotography – reference plots
Browsing pressure U, (T)	– special sampling plots for analysis of natural regeneration – field description of forest – analysed parameters of shoot game – harvest timber recording (esp. sanitary cut) – permanent sampling plots
Forest fragmentation U	– GIS
Stand structure: – BHD structure U, (T) – horizontal stand structure U, (T) – presence and abundance (portion) of particular developmental phases or stand types U	– field description of forest – permanent sampling plots – GIS – reference plots
Stand quality U, T, (S)	– field description of forest
Dead wood U	– permanent sampling plots
Others (growing stock, key habitats, increment, etc.)	– various

availability. Therefore, we can only define some indicators in general, which are often very useful at the FMU level. For example, the most important indicators of ecosystem condition are presented in Table 1: forest area, percentage of forest cover, forest distribution, tree species composition and its alteration, portion of developmental phases, natural regeneration (composition, abundance, height structure, level of browsing pressure), diameter stand structure, growing stock, dead wood, amount of sanitary cut, horizontal and vertical stand forest structure, stand quality, percentage of natural regeneration in total regeneration, etc.

All the above mentioned information is not only important for SFM evaluation, but also for the planning process as a whole (Figure 3). The 'treatment indicators' are not mentioned, because they are well known in the Central European forest theory and praxis. They are a part of 'Erfolgskontrolle' (German) and managerial economics (Sekot 1991; Tschupke 1986).

4.1.2 Reference values and some dilemmas of their use

Generally, reference values may be used in different ways (Bernasconi 1996; Boncina 2000):

- Normal (ideal, optimum) reference value. For example, actual proportion of forest developmental phases is compared to a normal one.
- Threshold (critical, maximum, minimum) reference value of a chosen SFM indicator presents a critical value for sustained forest functioning. For example, minimum amount of natural regeneration, or minimum average growing stock, or minimum forest covered area, etc.
- Normative reference value, as a result of an agreement among different subjects. For example, allowed damage level of natural regeneration due to browsing pressure as an agreement between hunters and foresters.

Reference values for some SFM indicators are easily determined. For example, the ideal reference value of the SFM indicator 'stand vitality and health' comes up to 100% representing a completely healthy and vital forest. The actual vitality and health of forest stands is compared with a completely healthy forest.

Reference values for other indicators are more difficult to determine. There are many dilemmas to determine. For example, the optimum or the minimum reference value of dead wood amount, the reference value of optimum DBH structure of forest stands, or the maximum allowable level of regeneration damage due to browsing pressure. In the cases mentioned above, the determination of reference values depends on site and stand conditions as well as of management goals. For example, in some forest types a higher amount of dead wood is necessary compared with other forest types.

Reference values of some indicators can be defined empirically by adapted forest management, which is based on monitoring of forest development, previous forest activities and their influence on forest structure. Reference values were very often determined not experimentally, but *a-priori*, by a formal-mathematical approach, which was typical of 'classic' forest management. This was very often against the nature of the forest. For example, negative exponent (de Liocourt 1898) distribution was used as a reference (normal/ideal) diameter structure of uneven-aged forests.

Many reference values cannot be defined in the forestry planning, especially those regarding biodiversity. In the framework of forest planning only some of the indicators can be monitored, but neither exact correlation between some indicators and SFM criteria nor their optimum and critical reference values are known. The research results carried out on comparable reference plots can be an important substitutional source of reference values.

4.1.3 Evaluation of ecological SFM indicators – two examples

Case 1: tree species composition and its alteration

Tree species composition is an important SFM indicator (Table 1). The actual tree species composition at different spatial levels is compared with the 'natural' proportion of trees species as a reference value, applying an index (I_d) for estimating species alteration (Boncina and Robic 1998; Robic 1988). Reference values are defined for the site types by means of forest reserves and other reference plots or by phytocoenological research.

When using the index for estimating species alteration we should be aware of some weak points of such an approach. The reference value should be understood as a frame value for a particular site type. Tree species composition naturally changes over time.

$$I_d = \frac{100 \cdot \sqrt{\sum (S_i - M_i)^2}}{\sqrt{\sum S_i^2 + \sum M_i^2}}$$

I_d index of (tree) species alteration
i = 1, ..., n particular tree species
N total number of different tree species
M_i reference value of tree species composition, expressed in% of total growing stock
S_i actual value of tree species composition, expressed in% of total growing stock

Due to economic reasons tree species composition of forests can be changed. However, the more the composition and structure of forest stands is changed, the greater are the possibilities for economically undesired development of forest community (e.g. problems with natural regeneration, stability, etc.). One could define a threshold or a critical reference value of alteration of tree species composition at the levels of forest type or landscape.

Table 2. An example for index (I_d) calculation.

Tree species	Reference value	Actual values		
		stand 1	stand 2	stand 3
Fir	40%	20%	10%	0%
Beech	60%	80%	40%	0%
Spruce	0%	0%	50%	100%
Alteration index (I_d)		26%	64%	100%
Alteration index class (20%)		2	4	5

Allowable alterations of tree species composition are certainly different for different forest sites. On some forest sites, tree species composition can be changed to a large extent without any noticeable consequences for the ecosystem function. On another forest site, the same alteration of natural tree species composition (I_d) can cause serious disturbances in the ecosystem function. Spatial scale is also important; great alteration of natural tree species composition at the stand level is not equal to the same alteration at the landscape level. It is likely that nobody is able to define critical reference values for allowable alteration of tree species composition at once. However, through experiences obtained in the process of adapted forest management, it is possible to determine frame reference (critical) values.

In spite of all of the above, the index (I_d) can be a useful tool for evaluation of tree species composition as it is an important SFM indicator. It provides a simple way of presenting the problem of tree composition alteration at different spatial levels – and also at the FMU level.

Case 2: diameter structure of uneven-aged forests

In past forest management, the diameter structure was the main tool for monitoring and planning in uneven-aged (selection) forests. The basic rule was that the number of trees ingrowing into a particular diameter class should be equal to the sum of the harvested trees number in this DBH class and the number of trees outgrowing into the next DBH class (François 1938; Hufnagl 1892). The uneven-aged (selection) forest which enabled a sustained yield was called a 'normal (ideal) selection forest'. It was usually defined by the normal (ideal) diameter structure. It was determined in different ways, very often formally – mathematically based on some presumptions (Liocourt 1898; Meyer1933). Comparison of actual and normal diameter structure was a starting point for decision, especially for the determination of allowable cut. Recently, forest management in the uneven-aged forests has been improved (e.g. Schütz 1989; Hanewinkel 1999; Bachofen 1999). Three relevant conclusions regarding evaluation of sustainability in selection forests can be agreed upon:

1. Sustainability of uneven-aged forest cannot be evaluated just by using diameter structure as an indicator. When controlling selection forest several different stand parameters have to be taken into account at the same time (e.g. diameter structure, distribution of growing stock per diameter classes, number of trees in the smallest diameter class counted, natural regeneration, tree species composition, vitality, growing stock and increment, quality, etc.).
2. Comparison of actual and reference values of a chosen indicator (e.g. diameter structure, growing stock, vitality, etc.) is necessary to supplement by analysis of indicator's development and previous selection management.
3. Negative (declined) exponential distribution is not always suitable to represent the 'ideal' diameter structure of a selection forest. Different researchers state that selection forests with surplus of thick trees function well, and therefore, it is not appropriate to adapt an actual diameter structure to the normal one described by exponent function (Figure 5).

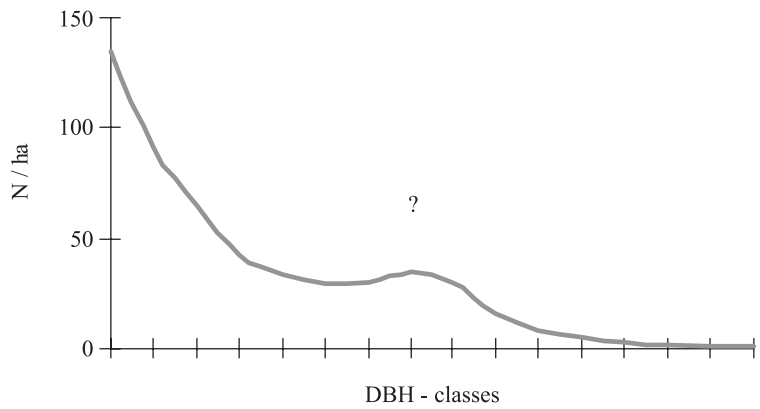

Figure 5. One of the possible ideal (reference) diameter structures of a selection forest stand (Boncina 2000).

4.1.4 Analysis of forest development and previous forest management as an important part of SFM

Analysis of forest development and previous forestry measures (Figure 3) is useful for SFM evaluation, as is the comparison of reference and actual values of SFM indicators. The analysis of forest development is based on periodical forest inventories enabling us to obtain an insight into the development of key forest parameters and answers to the following questions:

- How has tree species composition been changed?
- Has the area of old-growth forest stands increased?
- Is the vitality of forest stands better than 10, 20 or more years ago?
- Are there any changes in the process of natural regeneration?
- Is the quality of harvested timber better than 10 or more years ago?
- How have incomes and costs changed during this period?

Besides the monitoring of forest development, the monitoring of all forestry activities is needed, especially of cut as the main tool of forest tending. At the level of FMU in Slovenia all harvested trees are registered in the forestry information system (their number, DBH-classes, year, location, harvest type, tree species, etc.). Registration of different silvicultural and protection measures is also important (type, range, location, year, etc.).Contemporary comparison of all performed forestry measures on one hand, and forest development on the other hand, enable us to assess the efficiency of SFM and to gain experience, which could be used in future management decisions. This approach is a constituent part of adapted forest management.

5. Discussion

SFM is a very important process – at the expert and political level, and at the coarse and fine spatial scale (Angelstam and Pettersson 1997; Aplet et al. 1993; van Bueren and Blom 1997; MAFF 1998; IUCN et al. 1991). Efforts to define criteria and indicators of SFM and to reach their comparativeness on the international, regional or even FMU level are a part of this process, in which various problems arise. Many definitions, criteria and indicators of SFM are more useful at the national level than at the lower levels (e.g. at the FMU level). Some intentions to accept uniform procedure of SFM evaluation at different spatial levels are evident. Any procedure that can be used everywhere is likely to be so general as to be of little value in particular system of SFM. The rigid use of hierarchical concept of SFM evaluation (van Bueren and Blom 1997) based on a limited number of indicators and their reference values, both determined in advance, is probably not appropriate. The evaluation has to be adapted to given ecological, economic and social circumstances, which can differ greatly between different FMU even in the same region.

Procedure of SFM evaluation seems to be clear, but there are many questions regarding reference values. Efficiency and applicability of SFM evaluation depends on many facts: (1) how reference values are determined; (2) how they are understood; and (3) how they will be applied in the decision making process. Following are some suggestions for improvement of the SFM evaluation:

- Reference values have to be adapted to site conditions, stand structure and composition, and above all to management goals.
- Reference values can be defined either by adequate research of reference objects or through experiences in the adapted forest management based on monitoring of forest

development. Foresters can monitor the actual indicator values (e.g. tree species composition, stand structure, dead wood amount, etc.), but they sometimes do not know, what the reference value (minimum or optimum, etc.) for the particular indicator should be or they do not know, what is the relation (correlation) between indicator and SFM criterion (e.g. dead wood, biodiversity). It is up to the scientists to answer this question.
- Reference values should be understood as frame values. Therefore, a comparison between actual and reference values of indicators presents only an outline for improved forestry activities.
- Two approaches are of equal importance for SFM evaluation, as they supplement each other: (1) monitoring of forest development and previous forestry measures; and (2) comparison of actual and reference indicator values of SFM.

The evaluation of SFM indicators is somehow overestimated – a great emphasis is given to criteria and indicators of SFM. However, SFM evaluation is only the first step to realise SFM in the praxis, all others are of equal importance; the concept of sustainability should be respected in the entire planning process, and integrated in the implementation of planned activities.

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Programme

Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level

Nancy, France • 21–25 March, 2000

Tuesday, 21 March

Morning Session:

Opening Ceremony

Invited Keynote Speaker: *Peter Duinker (Canada)*

Afternoon Session:

Session I: Economic and Participation Issues in Sustainable Forest Management

Moderator: *Carol Colfer (CIFOR)*

Invited Speakers: *Birger Solberg (Norway)* and *Alain Karsenty (France)*

Impacts of Salmon Recovery Efforts on Towns and Cities in the Pacific Northwest of the U.S: Results from a Community-Based C&I Assessment. *Charles C. Harris, William J. McLaughlin, Erik A. Nielsen and Dennis R. Becker (USA)*

The Characteristics of Forest Management by Forest User Groups in Nepal and the Implications of This in Terms of Sustainability. *Edwin Keizer*

Economic Criteria and Indicators: Do They Provide for Sustainability Based on the Bolivian Experience? *BOLFOR Project (Bolivia*)

Assessment of Forest Sustainability. *H. Omari Malilo(Tanzania*)

Session II: Social Issues in Sustainable Forest Management

Moderator: *Birger Solberg (Norway)*

Invited Speaker: *Susannah Hecht (SA/Brazil)*

Alain Franc, Olivier Laroussinie and Timo Karjalainen (eds.)
Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level
EFI Proceedings No. 38, 2001

Review of Social Criteria and Indicators in Context of Participatory Forest Management in India. *Jayesh Bhatia (India*)

Field Testing Criteria and Indicators for Workers in Ghana. *Ion Iorgulescu, Jill Bowling and Rodolphe Schlaepfer (Switzerland*)

Usin ILO Texts to Define Social C&I for SFM. *Peter Poschen (Germany*)

Sustainable Forest Management from the User's Perspective in Tropical Countries. *Rekha Singhal (India*)

Wednesday, 22 March

Morning Session:

Group Discussions

Afternoon Session:

Session III: Biodiversity Issues in Sustainable Forest Management

Moderator: *Lisa Sennerby-Forsse, Sweden*

Invited Speakers: *Per Angelstam, Sweden and Tor-Björn Larsson (Sweden)*

A Model Indicating Biodiversity and Recreational Consideration in Forestry on Stand Level. *Lennart Eriksson and Anders Lindhagen (Sweden*)

Indicators of Population Viability in Small, Isolated Stands of Rare and/or Declining Tree Species: Reproductive and Genetic Status of Red Spruce, *Picea rubens.*
A. Mosseler, O.P. Rajora and J. Major (Germany*)*

Indicators for the Assessment of the Predisposition of Spruce-Abundant Forest Ecosystems to Various Disturbant Factors. *U. Nopp, S. Netherer and E. Führer (Austria*)

Session IV: Modelling and Quantitative Approaches for Assessing Sustainability of Diversity

Moderator: *Jacques Weber, France*

Invited Speaker: *Bryan Finegan, Costa Rica*

Modification to the Forest Inventory of the National Forest of Leira for Application of the C&I for SFM. *Margarida Tomé, Paula Soares, Paulo Canaveira and Suzana Gomes (Portugal*)

Development of a Multicriteria Decision Support System Applied to Multiple-use Forest Management: Application to Forest Management at the Management Unit Level in South-Belgium. *Emmanuelle Bousson (Belgium*)

Site Based Monitoring – How Many, How Often and How Long? *B. Farthing, T. Eyre, P. Norman and K. Mengersen (Australia*)

The Use of Predicting Models of Breeding Bird Assemblages for Assessing and Monitoring Forest Biodiversity. *Jean-Luc DesGranges, Patrick Agin, Samy Bengio and Pierre Belleau (Canada*)

Thursday, 23 March

Morning Session:

Group Discussions

Afternoon Session:

Session V: Assessment of C&I for SMF at Stand Level

Moderator: *Lammerts van Bueren, Tropenbos Foundation (Netherlands)*

Indicators for Applied Sustainable Forest Management: a Case Study as a Basis For Ecological Normality. *F. d'Aprile (Australia*)

Landscape Visualisation Software as a Forest Management Decision Support System. *Daniel Auclair, Frédéric Borne and Michel Étienne (France*)

Case Study at the Haliburton Forest & Wild Life Reserve Ltd. *Thorsten Mrosek (Canada*)

Session VI: Integration of C&I for SMF at Regional Level

Moderator: *Jean-Guy Bertault (France)*

Invited Speaker:*V.P. Mohan (India*)

Tropenbos Hierarchical Framework for the Formulation of Sustainable Forest Management Standards. *Lammerts van Bueren and E.M. Blom, Tropenbos Foundation (Netherlands*)

Implicit and Explicit Paradoxes in Managing Certified Forests in the United States. *Theodore E. Howard (USA*)

Concept of Evaluation of Sustainable Forest Management at the Forest Management Level in Slovenia: Some Characteristics, Problems and Suggestions. *Andrej Boncina (Slovenia*)

SFM Standards as Instruments for a Better Communication to the Forest Operators and the Public. The Experience of an Italian Region. *D.M. Pettenella and I. Nobili (Italy*)

Canada's Model Forest Experiences in Developing and Working with Local Level Inciators of Forest Sustainablility. *Louis LaPierre (Canada*)

Friday, 24 March

Morning Session:

Group Discussions

Afternoon Session:

Global Discussion

Concluding Keynote Speakers: *Richard Guldin (USA) and Christian Barthod (France*)

Saturday, 25 March

Excursion: A one-day excursion will be organized to the surroundings of Nancy, in co-operation with local forest managers and researchers, to illustrate the problems with the implementation of C&I for sustainable forest management at two different forest management unit levels. Two visits are planned:

1. Romersberg State Forest. Topic: 'Implementation of C&I in the context of the multifunctional forest management plan of a state forest'.
2. Lorraine Regional Natural Park. Topic: 'Sustainable forest management in a natural Park, organisation with forest owners (private and public), and the role of C&I in the process'.

Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level

21–25 March, 2000
Nancy, France

Ekko Aertsen
Stichting Robina
PO Box 494
6700 Al. Wageningen
Netherlands
Tel. +31 317 427570
Fax. +31 317 419020
Email Strobini@bos.nl

David Balsillie
University of Toronto
Faculty of Forestry-Earth Sciences Centre
33 Willcicks Street
M5S 3B3 Toronto
Canada
Tel. +1.416.978.4638
Fax. +1.416.978.3834
Email david.balsillie@utoronto.ca

Per Angelstam
Swedish University of Agricultural Sciences
Consevation Biology
Grimsö Wildlife Research Station
730 91 Riddarhyttan
Sweden
Tel. +46 581 697 300
Fax. +46 581 697 310
Email per.angelstam@nvb.slu.se

Rainer Baritz
State Forest Research Station Baden-Württemberg
Wonnhaldestr. 4
79100 Freiburg
Germany
Tel. +49 761 4018 117
Fax. +49 761 4018 333
Email baritz@fva.bwl.de

Daniel Auclair
Unite deModelisation des Plantes
CIRAD
BP 5035
34032 Montpellier
France
Tel. +33 4 6759 3850
Fax. +33 4 6759 3858
Email auclair@cirad.fr

Nicolas Barriere
Eurocertifor
28, rue de Solférino
92100 Boulogne Billancourt
France
Tel. +33 1 55 20 06 23

Alain Franc, Olivier Laroussinie and Timo Karjalainen (eds.)
Criteria and Indicators for Sustainable Forest Management at the Forest Management Unit Level
EFI Proceedings No. 38, 2001

Jean-Hugues Barthet
ONF
5, rue Girardet
54042 Nancy Cedex
France

Jean-Guy Bertault
CIRAD-Forêts
TA 10/B Campus International de Baillarguet
34398 Montpellier cedex 5
France
Tel. +33 4 6759 3753
Fax. +33 4 6759 3755
Email bertault@cirad.fr

Sokol Bezhani
Directorate General of Forest & Pasture
RRUGA - Sami Frasheri - no. 4
Tirana
Albania
Tel. +355.42.56785
Fax. +355.42.56785

Yves Birot
INRA-FMN
Département des Recherches Forestières
19 Av. du Maine
75732 Paris Cedex 15
France
Tel. +33 1 45 49 89 75 / 8880
Fax. +33 1 45 48 88 39
Email lagarrig@paris.inra.fr

Andrej Boncina
University of Ljubljana
Biotechnical Fac., Dept of Forestry
Vecna pot 83
1000 Ljubljana
Slovenia
Tel. +386 61 123 1161
Fax. +386 61 271 169
Email andrej.boncina@uni-lj.si

Marc Bonnet-Masimbert
INRA
Département Forêts et Milieux Naturels
BP 20619
45166 Olivet Cedex
France
Tel. +33 2 3841 7800
Fax. +33 2 3841 7859
Email masimber@orleans.inra.fr

Emmanuelle Bousson
Fac. Uni. des Sciences Agronom.
Unité de Gestion et Economie For.
Passage des Déportés 2
5030 Gembloux
Belgium
Tel. +32 81 622 297
Fax. +32 81 622 301
Email bousson.e@fsagx.ac.be

Michael Bredemeier
Forest Ecosystems Research Centre
Buesgenweg 1
37077 Goettingen-Weende
Germany
Tel. +49 5513 93512
Fax. +49 5513 99762
Email mbredem@gwdg.de

Monika Breuss
Depart of Wildlife Biology and game management
Peter Jordan Str. 76
Vienna
Austria
Tel. +225 45 72 07
Fax. +43 1 47654 4450
Email monikabreuss@netscape.net

Michel Buffet
ENGREF
14,rue Girardet
54042 Nancy Cedex
France

Gérard Buttoud
ENGREF
14, rue Girardet
54042 Nancy Cedex
France
Email buttoud@engref.fr

Michel Cantin
Ministere des Ressources Naturelles du Québec
880, Chemin Sainte-Foy
G1S 4X4 Québec
Québec, Canada
Tel. +418 627-8646 (4175)
Email michel.cantin@mrn.gouv.qc.ca

Jean-Michel Carnus
INRA
Station de Recherches Forestières
Domaine Hermitage Pierroton BP 45
33611 Cestas
France
Tel. +33 557 97 90 00
Fax. +33 556 68 02 23
Email carnus@pierroton.inra.fr

Froylan Castaneda
FAO
FORM
Room: A-366, Viale delle Terme di Caracalla
00100 Rome
Italy
Tel. +39 06 5705 3834
Fax. +39 06 5705 5137
Email Froylan.Castaneda@fao.org

Christophe Chauvin
CEMAGREF
Groupement de Grenoble
2 rue de la Papeterie, PO Box 76
38402 St Martin d'Heres Cedex
France
Tel. +33 4 7676 2772
Fax. +33 4 7651 3803
Email christophe.chauvin@cemagref.fr

Klever Chavez
Ministry of Enviroment
Amazonas y E. Alfaro, piso 8
Quito
Ecuador
Tel. +593 2 563486
Fax. +593 2 565809
Email kchavez@ambiente.gov.ec

Nugent Ciaran
Universty College Dublin
Department of Agricultural and Food Engineering
39, Dundas Str.
Ralsfort Terrace, Dublin 2
Ireland
Tel. +353 1 7067318
Fax. +353 1 7067481
Email silvics@indigo.ie

Carol J. Pierce Colfer
CIFOR
PO Box 6596 JKPWB
10065 Jakarta
Indonesia
Tel. +62 251 622 622
Fax. +62 251 622 100
Email c.colfer@cgiar.org

Sandrine Costa
ENGREF
14, rue Girardet
54042 Nancy Cedex
France

Zita Costa
General Directorate of Forest
Av. João Crióstomo, 26-28
1069-040 Lisboa
Portugal
Tel. +35 121 31 24 903
Fax. +35 121 31 24 989
Email zita.costa@dgf.min-agricultura.pt

Guenaelle Couderc
AFOCEL
Domaine de l'Etançon
77370 Nangis
France
Tel. 01 60 67 00 35
Fax. 01 60 67 00 36
Email Couderc@afocel.fr

Fabrizio D'Aprile
Institute of Land & Food Resources
University of Melbourne - Dept. of Forestry
Parkville 3052
Melbourne
Australia
Tel. +61 3 5277 1791
Fax. +61 3 5277 1791
Email fdaprile@smartchat.net.au

Mads Dalsgaard
Danish Forest and Landscape Research Institute
Hoersholm Kongevej 11
Hoersholm
Denmark
Tel. +45 451 78339
Fax. +45 457 63233
Email mda@fsl.dk

Dominique Danguy des Deserts
ENGREF
14, rue Girardet
54042 Nancy Cedex
France
Tel. +33 3 83 39 68 00
Fax. +33 3 83 39 32 54
Email danguy-des-deserts@engref.fr

Roger De Legge
EUROCERTIFOR
28, rue de Solférino
92100 Boulogne Billancourt
France
Tel. 01 5 5 20 06 23
Fax. 01 5 5 20 06 24
Email info@eurocertifor.com

Mairin Delaney
Coillte Teoranta
Irish Forestry Board
Newtownmountkennedy
County Wicklow
Ireland
Tel. +353 1 2011160
Fax. +353 1 2011199
Email delaneym@indigo.ie

Jean-Luc Desgranges
Canadian Wildlife Service
1141 Route De L'église
CP 10100
G1V 4H5 Sainte-Foy
Quebec, Canada
Tel. +418-649 6126
Fax. +418-649 6475
Email jean-luc.desgranges@ec.gc.ca

Susana Dias
Estação Florestal Nacional
Tapada Nacional das Necessidades
Rua do Borja, 2
Lisbon
Portugal
Tel. +3 51 390 16 61
Fax. +3 51 213 97 31 63
Email s.dias@mail.telepac.pt

Karel Drápela
Mendel Univ.of Agr. and Forestry
Inst. of Forest Management
Zemedelská 3
613 00 Brno
Czech Republic
Tel. +420 5 4513 4141
Fax. +420 5 4521 1422
Email drapela@mendelu.cz.

Peter N. Duinker
Dalhousie University
School for Resource & Environmental Studies
1312 Robie St.
Halifax, NS, B3H 3J5
Canada
Tel. +1 902 494 7100
Fax. +1 902 494 3728
Email pduinker@is.dal.ca

Jean-Luc Dupouey
INRA
Forest Ecophysiology Unit
54280 Champenoux
France
Tel. +33 3 8339 4049
Fax. +33 3 8339 4022
Email dupouey@nancy.inra.fr

Bernard Dupuy
Cirad Forest
B.P. 5035
34032 Montpellier
France
Fax. 04 67 59 37 69
Email bernard.dupuy@cirad.fr

Lennart Eriksson
Dept. of Forest Management and Products
PO Box 7060
SE-750 07 Uppsala
Sweden
Tel. 46 18 671 279
Fax. 46 18 673800
Email lennart.eriksson@sh.slu.se

Brendan Farthing
Centre in Science and Industrial Mathematics
QUT-School of Mathematical Sciences
GPO Box 2434
Brisbane
Australia
Fax. +61 7 3896 9858
Email b.farthing@fsc.qut.edu.au

Bryan Finegan
CATIE
Adartado 93
7170 Turrialba
Costa Rica
Tel. +506 556 6021
Fax. +506 556 1533
Email bfinegan@catie.ac.cr

Mohamed Fofana
Direction Nationale de Eaux et Forests
Dixinn
Conakry
Guinee
Fax. +225 45 72 07
Email sita@mirinet.net.gn

Paulette Louise Ford
Rocky Mountain Research Station
2205 Columbia Se
87106 Albuquerque
New Mexico
USA
Tel. (505) 766 1044
Fax. (505) 766 1046
Email pford/rmrs_albq@fs.fed.us

Alain Franc
ENGREF
19 Avenue du Maine
75732 Paris Cedex 15
France
Tel. +33 145 498 982
Fax. +33 145 498 839
Email franc@engref.fr

Georg Frank
Federal Forest Research Center
Dept of Silviculture
Hauptstr. 7
A-1140 Vienna
Austria
Tel. +43 1 979 6719
Fax. +43 1 979 6384
Email Georg.Frank@fbva.bmlf.gv.at

Réjean Gagnon
Université de Québec à Chicoutimi
Consortium de Recherche s/l Forêt Boréale
Comm.
555 Boulevard de l'Université
Chicoutimi, QC G7H 2B1
Canada
Tel. +1 418 545 5011 ext 5072
Fax. +1 418 545 5012
Email rgagnon@uqac.uquebec.ca

Jürgen Geldbach
Federal Ministry of Food, Agriculture and
Forestry
Rochusstraße 1
53123 Bonn
Germany
Tel. +49 228 529 3741
Fax. 49-0228 5294276
Email juergen.geldbach@bml.bund.de

Jaboury Ghazoul
University of London
Imperial College
Silwood Park, Ascot
SL5 7PY Berkshire
UK
Tel. 01344 294 536
Fax. 01344 294 308
Email j.ghazoul@ic.ac.uk

Simon Gillam
Forestry Commission
231 Corstorphine Road
Edinburgh EH12 7AT
UK
Tel. +44 131 314 6280
Fax. +44 131 314 6506
Email simon.gillam@forestry.gov.uk

Marion Gosselin
CEMAGREF
Domaine des Barres
45290 Nogent sur Vernisson
France
Tel. 02 38 95 03 49
Fax. 02 38 95 03 46
Email marion.gosselin@cemagref.fr

Carlos A. Gracia
University Barcelona
CREAF, Dept of Ecology
Avda Diagonal 645
8193 Barcelona
Spain
Tel. +34 93 402 1511
Fax. +34 93 411 1438
Email gracia@porthos.bio.ub.es

Richard Guldin
USDA Forest service
Po Box 96090
20090-6090 Washington DC
USA
Tel. 202 205 1507
Fax. 202 205 1551
Email rguldin/wo@fs.fed.us

Dalip Habili
Institutii Kerkimeve Syjore
RRUGA Niko Avrami
Tirana
Albania
Tel. 355 42 57685
Fax. 355 42 56785

Charles Harris
University of Idaho
College of Natural Resources
83843-1139 Moscow-ID
USA
Tel. 208 88 6314
Fax. 208 885 1139
Email charris@uidaho.edu

Yasumasa Hirata
Forestry and Forest Products Research Institute
1 Mastsunosato
Kukizaki, Ibaraki
Japan
Tel. +81 298 73 3211
Fax. +81 298 73 3799
Email hirat09@ffpri.affrc.go.jp

Ted Howard
University of New Hampshire
Department of Natural Resources
James Hall 215 UNH
Durham
USA
Tel. 603 862 1020
Fax. 603 862 4976
Email tehoward@christa.unh.edu

Ryoko Ishizaki
Forestry and Forest Products Research Institute
Forest Policy and Economics Department
Matsunosato 1
305-8687 Kukizaki-machi. Ibaraki
Japan
Tel. +81 298 73 3211 ext. 639
Fax. +81 298 73 3799
Email ryokoi@ffpri.affrc.go.jp

Xavier Izko
Probona
Atahualpa 955 y Republica
Quito
Ecuador
Tel. +593 2 4666622
Fax. +593 4666624
Email xavier.izko@probona.sur.iucn.org

Hervé Jactel
INRA, Unité de Recherches forestières
BP 45, Domaine de l'Hermitage
F-33610 Pierreton Cedex
France
Tel. +33 557 979 027
Fax. +33 556 689 546
Email jactel@pierreton.inra.fr

Genci Kacorri
RRUGA "Sami Frasheri" no 4
Tirana
Albania
Tel. 355 42 56785
Fax. 355 42 56785

Shpresa Karadumi
RRUGA "Sami Frasheri" no 4
Tirana
Albania
Tel. 355 42 56785
Fax. 355 42 56785

Leena Karjalainen-Balk
Ministry of the Environment
Land Use Department
PO Box 380 or Kasarminkatu 25
00131 Helsinki
Finland
Tel. +358 9 1991 9443
Fax. +358 9 1991 9364
Email Leena.Karjalainen-Balk@vyh.fi

Edwin Keizer
ITC-Forest Science Division
Hengelosestraat 99
7500 AA Enschede
Netherlands
Tel. +31 53 4874330
Fax. +31 35 4874399
Email keizer@itc.nl

Emil Klimo
Mendel University of Agriculture and Forestry
Faculty of Forestry and Wood Technology
Zemedelská 3
61300 Brno
Czech Republic
Tel. +420 5 4513 4038
Fax. +420 5 4513 4180
Email tesarjar@mendelu.cz

Oforikuma Kojo
Choose Africa Ghana Limited
PO Box 13272
W/A 23321 Accra
Ghana
Tel. +2 33 24 23 21 81
Fax. +2 33 21 50 82 99
Email GH264@africaonline.com.gh

Genti Kromidha
Ministry of Agriculture and Food
RRUGA “Sami Frasheri” No. 4
Tirana
Albania
Tel. +355 4256 795
Fax. +355 4256 785
Email znprifti@albaniaonline.net

Jiri Kulhavy
Mendel Univ. of Agr. and Forestry
Institute of Forest Ecology
Zemedelská 3
61300 Brno
Czech Republic
Tel. +420 5 4513 4179
Fax. +420 5 4513 4180
Email kulhavy@mendelu.cz

Ivo Kupka
University of Agriculture
Faculty of Forestry
Kamycka 127
16521 Praha 6, Suchdol
Czech Republic
Tel. +420 2 2438 3791
Fax. +420 2 2092 3132
Email kupka@lf.czu.cz

Erik Lammerts van Bueren
Tropenbos Foundation
PO Box 323
6700 AE Wageningen
Netherlands
Tel. 31 317 426262
Fax. 31 317 423024
Email tropenbos@iac.agro.nl

Louis Lapierre
Canadian Model Forest Program
University of Moncton
E1A 3E9 Moncton
Canada
Tel. +1 506 858 4152
Fax. +1 506 863 2000
Email lapierl@umoncton.ca

Olivier Laroussinie
Forest Ecosystem (ECOFOR)
19, avenue du Maine
75732 Paris Cedex 15
France
Tel. +33 145 498 836
Fax. +33 145 498 839
Email laroussinie@engref.fr

Tor-Björn Larsson
Swedish Environmental Protection Agency
Blekholmsterrassen 36
10648 Stockholm
Sweden
Tel. +46 8 698 1447
Fax. +46 8 698 1663
Email tor-bjorn.larsson@environ.se

Christian Laurent
Ministry of the Walloon Region
DG Ress. Naturelles et Environnement
Av. Prince de Liège 15
5100 Namur
Belgium
Tel. +32 81 335 842
Fax. +32 81 335 833
Email C.Laurent@mrw.wallonie.be

François Le Tacon
INRA
Centre de Nancy
54280 Champenoux
France
Tel. +33 3 8339 4041
Fax. +33 3 8339 4069
Email le-tacon@nancy.inra.fr

Anders Lindhagen
Swedish University of Agricultural Science (SLU)
Dept. of Forest Management and Products
PO Box 7060
75007 Uppsala
Sweden
Tel. +46 18 673 840
Fax. +46 18 673 800
Email anders.lindhagen@sh.slu.se

Markus Lindholm
University of Joensuu
Saima Centre for Env. Sci.
Linnankatu 11
FIN-57130 Savonlinna
Finland
Tel. +358 15 575 98 56
Fax. +358 15 575 98 52
Email markus.lindholm@joensuu.fi

Janar Male
RRUGA “Sami Frasheri” no 4
Tirana
Albania
Fax. 355 42 56785

Malle Mandre
Estonian Agricultural University
Dept. of Ecophisiology
Viljandi Road 18b
11216 Tallinn
Estonia
Tel. +372 6281 597
Fax. +372 6 281 599
Email mma@riigimets.ee

Gheorghe Marin
Research Institute for Forests
Sos. Stefanesti nr. 128, sector 2, O.P. 11
72904 Bucharest
Romania
Tel. +401 240 6095
Fax. +401 240 6845

Jaroslav Martinek
Training Forest Enterprise
University of Agriculture and Forestry
Krtiny 175
67905 Krinity
Czech Republic
Tel. +420 506 439 115 16
Fax. +420 506 439101

Jorge Meza
Ministry of Enviroment
E. Alfaro y Amazonas, MAG, piso 8
Quito
Ecuador
Tel. +593 2 507 630
Fax. +593 2 506 446
Email jmeza@engref.fr

Genevieve Michon
IRD co.ENGREF-FRT
BP 5093
34033 Montpellier
France
Tel. 04 67 04 71 00
Fax. 04 67 04 70 01
Email michon@engref.fr

Moman Mohan
International Institute for the Environment
Sunny Villa, Nigam Vihar
171002 Shimla
India
Tel. +91 177 223 953
Fax. +91 177 223 453

Francisco Moreira
Instituto Superior de Agronomia
Centro de Ecologia Aplicada
Tapada da Ajuda
1399 Lisboa codex
Portugal
Tel. +351 1 362 3493
Fax. +351 1 362 3493
Email ceabn@ip.pt

Thorsten Mrosek
University of Toronto
Faculty of Forestry - Earth Sciences Centre
33 Willcocks Street
M5S 3B3 Toronto
Canada
Tel. +1 416 978 4638
Fax. +1 416 978 3438
Email thorsten.mrosek@utoronto.ca

Robert Nasi
CIFOR
PO Box 6596 JKPWB
Jakarta 10065
Indonesia
Tel. +62 251 622 622 ext. 128
Fax. +62 251 622 100
Email r.nasi@cgiar.org

Simeon Nedyalfov
Academy of EEA
7 Slaveikov Sq.
9010 Varna, 1000 Sofia
Bulgaria
Tel. +359 52 302 493
Fax. +359 2 988 53 49

Sigrid Netherer
IFFF, University of Agricultural Sciences
Hasenauerstr. 38
A-1190 Vienna
Austria
Tel. +43 01 368 6352
Fax. 368 6352-97
Email netherer@ento.boku.ac.at

Niels Nielsen
Space Applications institute
Joint Research Centre
21021 Ispra
Italy
Tel. +39 033 2785 854
Fax. +39 033 27 89 469
Email NIELS.nielsen@jrc.it

Lisa Noël
ONF/ CS 52 19
5, rue Girardet
54052 Nancy cedex
France
Tel. 33 3 83 17 74 00
Fax. 33 3 83 32 09 89

Raymond N. Norman
SLYACDO
39, Dundas Street
Freetown
Sierra Leone
Tel. 00232 22 220273
Fax. +232 22 22 4439
Email slyacdo@yahoo.com

Christy O'Donovan
Forest Service - Civic Offices
Dungarvan
County Waterford
Ireland
Tel. +353 58 458 45
Fax. +353 58 458 808

Aileen O'Sullivan
Coillte Teoranta
Irish Forestry Board
Nextownmountkennedy
County Wicklow
Ireland
Tel. +353 1 201 11 60
Fax. +353 1 201 11 99
Email aileenos@indigo.ie

Christophe Orazio
IEFC
BP 45, Domaine de l'hermitage
33611 Gazinet Cedex
France
Tel. +33 5 5797 9061
Fax. +33 5 5668 0223
Email IEFC.aquitaine@netcourrier.com

Elena Paduraru
University of Iasi
Strada Moritel
Bacau
Romania
Fax. +40 32 21 16 85
Email cand@mail.dntis.ro

Frantisek Pasek
Ministry of Agriculture
Forestry Department
Tesnov, 17
11705 Prague
Czech Republic
Tel. +420 2 21 81 22 91
Fax. +420 2 21 81 29 88
Email pasek@mze.cz

Rui Manuel Pereira Simão
City-Hall of Lisbon
Cruz das Oliveiras-Parque Florestal de Monsanto
Lisbon
Portugal
Tel. +35 12 13 62 78 65
Fax. +35 12 13 63 92 34
Email rui_myceta@hotmail.com

Jean-Luc Peyron
INRA/ENGREF
14 rue Girardet
54042 Nancy Cedex
France
Tel. +33 3 8339 6800
Fax. +33 3 8330 2254
Email Peyron@ecny.nancy-engref.inra.fr

Michèle Phelep
Direction de la Recherche Forestière
Ministère de l'Agriculture
19, avenue du Maine
75732 Paris Cedex
France
Tel. +33 3 83 39 68 00

Dominique Piou
ENGREF
Arboretum des Barres
Les Barres
45290 Nôgent-sur-Vernisson
France
Tel. +33 2 3895 0270
Fax. +33 2 3895 0278

Jean-Noël Piroche
CEMAGREF
Domaine des Barres
45290 Nogent sur Vernisson
France
Tel. 02 38 95 03 49
Fax. 02 38 95 03 46
Email jean-noel.piroche@gemagref.fr

M. Rafailov
Universite des Forets
Sustainable Forest
Bull.Kliment Ohridski 10
BG-1156 Sofia
Bulgaria
Tel. +359 2 623 068
Fax. +359 2 623 068
Email bsfp@mail.netbg.com

Ewald Rametsteiner
MCPFE-Liaison Unit Vienna
Marxerg.2
Vienna
Austria
Tel. +43 1 710 77 02 16
Fax. +43 1 10 77 02 13
Email e.rametsteiner@lu-vienna.at

Jacques Ranger
INRA Centre de Nancy
Cycles Biogeochimiques
54280 Champenoux
France
Tel. +33 383 394 068
Fax. +33 383 394 069
Email ranger@nancy.inra.fr

Jean-Pierre Renaud
Office National des Forêts
22, rue de Herrlisheim
68000 Colmar
France
Tel. +33 3 8922 9617
Fax. +33 3 8979 7214

Jacques Robert
Service Canadien des Forêts
320, rue St-Germain est, Bureau 200B
G5L 1C2 Rimouski
Quebec, Canada
Tel. 418 721 5350
Fax. 418 721 5356
Email robert@cfl.forestry.ca

Kazimierz Rykowski
Forest Research Institute
Sekocin-las
Raszyn
Poland

Christophe Ryniekiewicz
44, rue de Tocqueville
75017 Paris
France
Tel. 06 60 50 96 23
Email rynikiew@isige.ensmp.fr

Cristina Santos
Forest Service
Av. Joao Crisostomo 26-28, 3
1069-040 Lisboa
Portugal
Tel. +351 1 312 4925
Fax. +351 1 312 4989
Email ç.santos@dgf.min-agricultura.pt

Richard Savard
Réseau Canadien des Forêts
300, Allée des Ursulines, bur.J-463
G5L 3A1 Rimouski, QC
Quebec, Canada
Tel. (418) 722 7211
Fax. (418) 721 5630
Email richard_savard@fmodsl.qc.ca

Lisa Sennerby-Forsse
Skogforsk
Uppsala Science Park
751 83 Uppsala
Sweden
Tel. +46 18 18 85 00
Fax. +46 18 18 86 00
Email lisa.sennerby-forsse@skogforsk.se

Mihaela Sescu
University of Iasi
Strada Principala
Sabaoani
Romania
Fax. 00 40 32 21 16 85
Email cand@mail.dntis.ro

Taghi Shamekhi
University of Tehran
Faculty of Natural Resources
31584 Karaj
Iran
Tel. +98 261 223 044
Fax. +98 218 007 988
Email tshamekh@ut.ac.ir

Kjell Sjoberg
Swedish University
Agricultural Sciences
Umea
Sweden
Tel. +4 69 07 86 66 10
Fax. +4 69 07 86 68 17
Email Kjell.Sjoberg@szooek.slu.se

Birger Solberg
Agricultural University of Norway
Department of Forest Sciences
PO Box 5044
1432 Aas
Norway
Tel. +47 64 948 928
Fax. +47 64 948 890
Email birger.solberg@isf.nlh.no

Geoff Stoneman
Department of Conservation & Land
Management
Locked Bag 104
Bentley Delivery Centre
Perth
Tel. 6 1 08 938 986 03
Fax. Australia
Email geoffs@calm.wa.gov.au

Gabriela Strugariu
University of Iasi
Strada Bicaz
Iasi
Romania
Fax. +40 32 21 16 85

Rudi Suchant
State Forest Research Station
Baden-Wuerttemberg
Wonnhalde Str.4
D-79100 Freiburg
Germany
Tel. +49 761 4018 117
Fax. +49 761 4018 333
Email suchant@fva.bwl.de

Jouni Suoheimo
Ministry of Agriculture and Forestry
Department of Forestry
PO Box 30, FIN-00023 Government
Helsinki
Finland
Tel. +358 9 160 88681
Fax. +358 9 160 2430
Email jouni.suoheimo@mmm.fi

Alpha Sylla
Direction Nationale des Eaux et Forêts
Dixinn
Conarky
Guinee
Fax. +225 45 72 07
Email sita@mirinet.net.gn

Ousmane Sylla
Direction Nationale des Eaux et Forêts
Dixinn
Conarky
Guinee

Ouk Syphan
Cambodian-German Forestry
Department of Forestry and Wildlife
No. 40, Norodom Alvd.
Phnom Penh
Cambodia
Tel. +855 12 810 223
Fax. +855 32 123 612
Email DFW.syphan@bigpond.com.fr

Daniel Terrasson
CEMAGREF
50 Avenue de Verdun
33612 Cestas Cedex
France
Tel. +33 5 57 89 01 94
Fax. +33 5 57 89 08 01
Email daniel.terrasson@cemagref.fr

Aude Tessier
ENGREF
14, rue Girardet
54052 Nancy Cedex
France

Tiina Vahanen
UN Secretariat of the Intergovernmental Forum on Forests
2 UN Plaza, Room # DC2-1284
10017 New York
USA
Tel. +1 212 963 3262
Fax. +1 212 963 3463
Email vahanen@un.org

Michel Vallance
Office National des Forêts
Département des Recherches Techniques
Boulevard de Constance
77300 Fontainebleau
France
Tel. +33 1 6074 9228
Fax. +33 1 6422 4973
Email dtc5onf@calvanet.calvacom.fr

Gijs van Tol
Ministry of Agriculture, Nature Management and Fisheries
PO Box 30
6700 AA Wageningen
Netherlands
Tel. +31 317 474 875
Fax. +31 317 474 930
Email g.van.tol@@iksn.agro.nl

Alessandro Wolynski
Provincia Automa di Trento
Ufficio Forestale Distrettuale
Via Fabio Filzi
38032 Cles
Italy
Tel. +39 0463 421 320
Fax. +39 0463 424 327
Email wolyn@iol.it

M. Yuroukov
Universite des Forets
Sustainable Forest
Bull. Kliment Ohridski 10
BG.1156 Sofia
Bulgaria
Tel. +359 2 623 068
Fax. +359 2 623 068
Email bsfp@mail.netbg.com

Filip Zadrima
Directorate General of Forest & Pasture
RRUGA “Sami Frasheri” no4
Tirana
Albania
Tel. 355 42 567 85
Fax. 355 42 567 85

Misak Zbynek
Czech University of Agriculture
Forestry Faculty
Kamycka 129
165 21 Prague 6
Czech Republic
Tel. +420 22 4383791
Fax. +420 23 258 63
Email misak@lf.czu.cz

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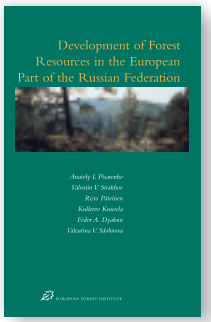

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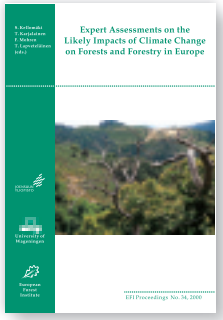

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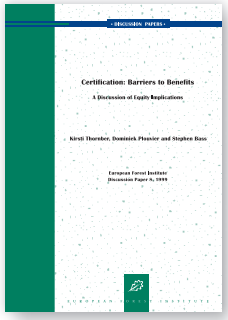

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