GLOBAL FIBRE SUPPLY STUDY
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Working Paper GFSS/WP/03

August 1997

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Agriculture
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by

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FOREWORD

In late 1995, the FAO Forestry Department initiated the Global Fibre Supply Study (GFSS) with an outlook to the year 2050. The study was recommended by the FAO Advisory Committee on Pulp and Paper (now the Advisory Committee on Paper and Wood Products). The general objective of the study is to contribute reliable data, information, forecasts and analysis of industrial fibre sources in order to promote sustainable forest management.

The GFSS will include a compilation of the latest available inventory data, including recovered and non-wood fibre, focusing primarily on the sources of industrial fibre as raw material for the sawmilling, wood-based panels, and pulp and paper industries. It will also include a projection and analysis of future developments in fibre supply, based on explicit consideration of the major factors affecting supply.

The GFSS is unique among FAO studies in that special emphasis is placed on collection and compilation of fibre volume inventory and growth data for the developing regions - Africa, Asia-Pacific, and Latin America and the Caribbean. The study complements other FAO work, such as the Asia-Pacific Forestry Sector Outlook Study and the upcoming Forest Resources Assessment 2000. FAO is also updating its statistics on forest plantations and developing a method for estimating fibre volumes from non-forest areas in the tropical regions. Available data from these studies will be included in the GFSS.

The major products of the GFSS will include:

- A database accessible on-line through the Internet providing estimates of commercial wood volumes from natural, semi-natural and plantation forests;
- An on-line interactive fibre-supply model incorporating key determinants of supply;
- A statistical and descriptive report on the data and three fibre-supply scenarios which are based on factors deemed to be the most critical;
- A working paper describing in detail the methods for data compilation, gap filling, data validation, forecasting and definitions, survey forms and country list;
- A series of additional working papers on sustainable forest management, improved forest productivity from industrial forest plantations, fibre-supply modelling, recovered and non-wood fibre, and other topics; and
- An issue of *Unasylva*, FAO’s quarterly journal on forestry and the forest industry, dedicated to the theme of global fibre supply.

This paper, solicited by the GFSS and co-authored by Jeremy Williams, Peter Duinker and Gary Bull, explores the concept of sustainable forest management and describes its potential implications for fibre volumes and costs. We sincerely hope that it contributes productively to the world-wide dialogue on sustainable forest management for fibre and other values.

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ACKNOWLEDGEMENTS

This series of working papers have seen the contribution of many silent partners. Our colleagues in the Forestry Department provided much needed advice on several issues. In addition, there have been many outside reviewers from different research institutions and technical cooperation agencies who have provided valuable information. We also want to thank our special assistant Ms Elisa Rubini who guided each report through the many technical hurdles in document preparation.

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SUMMARY

This study has examined evidence on the wood-supply implications of implementing sustainable forest management (SFM), biodiversity conservation, and certification. The concept of SFM has been broadened in recent years and the objectives of management are shifting in emphasis away from predominantly timber production towards ecological and social sustainability. Biodiversity conservation is widely seen as an integral component of SFM and provides an excellent example of the need to gain knowledge and develop means of assessing complicated forest values. Certification protocols are being developed by many of the forest-product exporting countries and regions of the world. In many cases, these are linked to SFM but not everyone agrees on the required strength of the linkage.

We have reviewed a suite of initial efforts to estimate the impacts of adopting SFM. However, many of these are based on simulation models and trial operations - few could be considered representative of contemporary operations. The studies reviewed here consistently showed that there will be widespread reductions in harvest volume, particularly in the short term, and costs can be expected to rise between 5 percent and 25 percent, on average. However, there is an expectation that long-term supply will increase through application of SFM. In the tropics, much of this increase is driven by the maintenance of site productivity and the retention of, and prevention of damage to, immature stems. In temperate forests, the longer-term increase is less pronounced and may not be captured without intensified silviculture. Instead, the value of the harvest may rise as more large and high-quality products are harvested.

Few studies report impacts of SFM adoption on costs. Of those that do, costs are generally expected to rise. There will be some additional costs of implementing certification, primarily associated with undertaking measures required to meet the certification standards, rather than the costs of the actual assessment. Because it is unclear how many companies will opt for certification, it is difficult to say whether there will be a significant impact on overall wood supply costs or volume.

A significant result of this study is that a number of driving forces will lead to significantly improved forest management practices. Throughout the world, there is pressure to improve forest management. Even if only a relatively small number of forest-products companies and forests become certified, it can be expected that the rest of the industry will continue to improve practices because the act of preparing certification criteria has raised the level of expected performance.

This general improvement entails a rebalancing of forest values and may lead to reduced timber-harvest volumes. Perhaps the relative value of non-timber forest values is rising faster than the value of timber, resulting in a reallocation of forest areas among competing uses, with the outcome of reduced timber harvests. However, in the longer term, there will be gains in some regions of the world as better management practices lead to the maintenance of timber productivity.

1. INTRODUCTION

The Global Fibre Supply Study was initiated in 1995 by FAO to update the organization's forecasts of global fibre supplies [FAO 1996]. To undertake the project, staff are building a country-specific database of the world's industrial roundwood supply using best available inventory data, developing separate supply estimates for each of the world's major production regions, and aggregating the results to develop a global estimate. Future supply will be sensitive to a number of factors affecting forest management which are not adequately handled in the timber-supply models. In particular, governments, NGOs, research institutes, universities, international organizations and forest-products companies throughout the world have recognized the need to modify forest management practices to ensure that the forests are used sustainably. While there is still a great deal of debate about how to assess sustainability and how to develop sustainable management paradigms, there are already some clear indications of coming changes.

Three such changes are likely to have a significant impact on either timber supply or the costs of procuring timber. They include:

- implementation of rigorous sustainable forest management (SFM) systems;
- development and implementation of forest and wood-product certification systems; and
- introduction of measures to conserve biological diversity (also known as biodiversity).

These measures are supported by a variety of global agreements, processes and policies, such as Agenda 21, the UN Forest Principles, and the 1992 Convention on Biological Diversity adopted at the United Nations Conference on Sustainable Development (UNCED). SFM, certification, and biodiversity conservation are inter-related in many ways. However, the nature of the linkages varies among countries and regions. Biodiversity conservation is widely viewed as an essential component of SFM - if biodiversity is being degraded, then management cannot be considered sustainable. Therefore, all credible SFM systems will have to include goals, objectives and indicators of biodiversity, and will eventually also need approaches for measuring or assessing levels of biodiversity.

There is more variation in the linkage between SFM and certification. Certification is one of the most controversial forestry issues today. In some countries, certification is seen as the outcome of an independent assessment of whether a forest area is managed sustainably or whether a particular product is made from wood fibre obtained from sustainably managed forests. According to this perspective, the broadest criterion for determining whether a forest is sustainably managed is whether the manager is following a well-defined SFM system designed for that forest. Critics of certification point to the potential for mis-use, and the questionable logic that consumers would make additional efforts or pay additional amounts to use certified products.

A great deal of literature has been produced on these topics during the past five years. However, there are still substantial gaps in our knowledge. Many ecosystem components and processes are poorly known and we understand little about how to measure the socio-economic impacts of alternative management systems. There is a large gap between our conceptual understanding of SFM and our ability to translate it into appropriate practices.

However, it is widely agreed that we must start now and work with the best available information, designing management practices to be efficient at helping us learn as we go.

1.1 SUSTAINABLE FOREST MANAGEMENT

SFM is a broad term that covers a range of new practices and extends the concept of sustainability far beyond the idea of sustained yield[1] that was so predominant in forest management until the mid- to late 1980s. Current visions of SFM require managers to conserve biological diversity, manage the forest to provide for non-consumptive values ranging from aesthetics to maintaining the forest for succeeding generations of people, and recognize that humans (especially aboriginal peoples) are part of the forest ecosystem. Other banners for contemporary forest management, such as ecosystem management and new forestry, are here considered to be consistent with and within SFM.

SFM was developed and refined from the original concept of sustainable development. Sparked by UNCED and re-inforced by numerous international efforts [see FAO 1997a], there are now several major international initiatives developing criteria and indicators of SFM (Table 1.1). These initiatives cover a huge area of the global forest.

Table 1.1: Ongoing international SFM initiatives by region

Ecological region	Initiative	Number of countries	Forest area (thousand ha)
Temperate and boreal forest	Helsinki Process	38	904 577
	Montreal Process	12	1 500 000
Tropical forest	ITTO Producer Countries	25	1 305 046
	Tarapoto Proposal	8	540 000
Dry-zone sub-Saharan forest	FAO/UNEP Dry Zone Africa	27	278 021
Dry-zone Near East	FAO/UNEP	30	69 895
All forest types	FAO Central America/Lepaterique Process	7	19 631

(Source: FAO 1997a)

SFM practices vary widely by forest type. In many tropical forest areas, the emphasis has been on reducing the damage associated with logging by using practices such as directional felling, developing detailed pre-harvest plans of roads, skid trails, and landings before harvesting, and trying to minimize damage to residual trees and the site. Efforts are also underway to modify the conventional approach of harvesting only a few commercial species and virtually eliminating them from the forest. In temperate forests, SFM is resulting in increased local input in decision-making, consideration of large-scale issues in planning, efforts to determine how to conserve forest biodiversity, and shifts in the way clearcutting is implemented.

[1] Sustained yield management referred to the ability to provide a predictable flow of timber in perpetuity. In many cases, implementation of sustained yield practices led to a future timber supply that was constant or increasing. Some authors argued that where the present forest had a very high standing volume, a reduction from present harvest levels to a lower sustainable level was permissible.

1.2 FOREST AND WOOD-PRODUCT CERTIFICATION

A second significant development in forest management is the impending implementation of certification systems. The essence of certification is a set of standards developed to ensure that a forest area is sustainably managed. Such standards are largely consistent with the concepts embodied in SFM. Some systems certify that defined forest areas are sustainably managed whereas others certify that specific products are made from wood from sustainably managed forests. The common element of these approaches is that forest sustainability must be assessed; product certification requires additionally that a wood tracking system be used to identify the source of every component and unit of final product.

Salim *et al.* [1997] cited two main objectives of timber certification:

- to provide a market incentive to improve forest management toward sustainable practices (SFM objective); and
- to improve market access and share for products of such management (trade objective).

To date, few forests have been certified and there has been little impact on markets. Many producer countries interested in certification are also major exporters (notably Indonesia, Malaysia, Sweden, Finland, Canada, and Ghana). They hope that certification will prevent future trade difficulties or provide preferential access to markets, as well as lead to improved forest management standards. On the consumer side, it is primarily European customers who have shown an interest. A variety of international agencies, including FAO, have taken an interest in certification. FAO supports the general thrust of certification on the grounds that it will lead to a wider adoption of sustainable management [FAO 1997b], while recognizing that there are many uncertainties and issues to be resolved. Byron and Perez [1996] offered the following outlook: “whether one sees it (certification) as a short-term fad, or a useful transition phase, is seems unlikely that 25 years from now, each piece of {tropical} timber will sport a green label . . . any more than that every item of cotton clothing sold will bear a label certifying that no DDT or slave labour was used in the growing of the cotton or making of the item.”

All of the credible certification processes developed so far take a broad view of forest management, and stipulate that the sustainability of forest operations must be confirmed by a set of appropriate indicators. This means that all forest values must be sustained, including biodiversity and ecosystem integrity. While the full impact of certification on wood supply will vary from region to region, a key assumption for any scenario is the proportion of the wood supply which will become certified. Some forest-products companies will doubtless choose not to become certified, but it is likely that the overall impact of certification initiatives will extend into positive changes in the practices of those companies. Thus, the certification initiative can be expected to raise the industry-wide standards of forest management.

1.3 CONSERVATION OF BIODIVERSITY

Forest managers have recently become aware of the importance of conserving biodiversity in forests. An internationally accepted definition of biodiversity is found in the 1992 Convention on Biological Diversity: “the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" [UNEP 1992].

Biodiversity is recognized at several levels within forest ecosystems. Genetic diversity refers to the level of variation within a population's gene pool; ideally, genetic material is retained and can be readily distributed in healthy populations. Species diversity refers to the variety of species present in a given area. Ecosystem diversity is the variety of ecosystem types, as defined by abiotic and biotic characteristics. In forestry, the ecosystems most at risk are usually mature forests dominated by commercially valuable tree species.

Biodiversity conservation is an important component of SFM - it preserves the resilience of ecosystems and ensures the continued existence of species. Some people argue that humankind has an ethical or stewardship responsibility to conserve biodiversity. A consensus is emerging concerning the elements that constitute biodiversity and the variety of spatial and temporal scales that should be considered in assessing its status [Duinker 1996a]. However, a great impediment is a lack of agreement on how it should be measured or assessed. Unfortunately, no company or agency can claim today to have a comprehensive system in place for conserving biodiversity, although many forest managers are implementing practices which will contribute to biodiversity conservation.

1.4 PROJECT TERMS OF REFERENCE

The objective of this project was to review available literature and interview knowledgeable researchers to estimate possible impacts on global fibre supply of implementing SFM, certification schemes, and biodiversity conservation measures. Most of the studies done to date on this subject are in the form of case analyses because there is great variability in local forests, supply-demand conditions, and forest practices. Case studies are not meant to provide a set of "correct" numbers for impact analysis, but they are indicative of possibilities. The results of the literature review are presented by region, and impacts expressed in terms of percentage changes in timber supply and wood cost.

FAO provided the following terms of reference for this study:

- Identify and estimate the impacts of ecosystem management practices and the implementation of the accompanying silvicultural systems on projected harvest volume (both per hectare and for the overall regional supply) and timber production costs by region;
- Review recent developments in wood certification and discuss the implications for forest management, using scenarios where appropriate to illustrate key points;
- Discuss the implications of biodiversity guidelines on future forest harvesting in terms of industrial roundwood volumes and wood quality;
- Provide a linkage between ecosystem management, wood certification and biodiversity guidelines and discuss and analyse their joint impact on fibre supply in the various regions, using examples where appropriate to illustrate key points.

Since biodiversity conservation is widely seen as a major component of SFM, the economic implications of implementing both SFM and biodiversity conservation are discussed together in the text below. The next section begins with an examination of the basic principles of SFM, then compares it to traditional sustained yield management, and finally provides some examples of how it is implemented in various parts of the world.

Many certification schemes requires forests to be managed by SFM principles (and certified wood products will have to come from such forests). However, many more forests may be managed by SFM principles than become certified. Hence, Section 3 will describe the results to date of estimates of how certification might affect forest-products markets. Section 4 provides a summary of the major findings and conclusions.

2. INTERPRETATIONS AND IMPLICATIONS OF SUSTAINABLE FOREST MANAGEMENT

2.1 OVERVIEW

For many years, pleas for environmentally friendlier management have come from environmental groups, the general public and certain quarters in the forestry profession [e.g. Leopold 1949]. In response, government forest-management agencies and the forest-products industry have recently introduced sweeping changes to forest management. These changes dramatically increase the scope of forest management and integrate ecological and social considerations with traditional timber management.

In retrospect, one can see that such a paradigm shift was developing for several decades. In the 1970s and 1980s, terms such as multiple use management, holistic resource management, and integrated forest management were used to describe environmentally sensitive alternatives (see Bull [1995] for a thorough review). Many of the approaches advocated during these years could be viewed as timber management with constraints. Critics argued that these approaches retained the dominance of timber and did not provide adequate weight to the other forest components.

The latest changes address this criticism and new terms have come into use. The language of the late 1980s and 1990s centres on the terms: (a) sustainable forestry [e.g. Kessler *et al.* 1992; Aplet *et al.* 1993; Murray 1993; Maser 1994]; (b) new forestry [e.g. Swanson and Franklin 1992]; (c) ecological integrity [e.g. Woodley *et al.* 1993; Noss 1995] and (d) ecosystem management [e.g. Agee and Johnson 1988; Mitchell *et al.* 1990; LeMaster and Parker 1991; USDA Forest Service Eastern Region 1992; Jensen and Bourgeron 1993; Forest Ecosystem Management Assessment Team 1993; Ontario Forest Policy Panel 1993; Grumbine 1994; Irland 1994; Jordan and Uhlig 1994; Kaufmann *et al.* 1994; Oliver 1994; Salwasser 1994; Daust 1995; Kohm and Franklin 1997].

SFM has come to serve as a common umbrella term for a wide range of improved forest management practices. Moreover, despite global differences in forest types, socio-economic importance of forests, and forest industry structure, an internationally accepted concept of SFM is emerging. In almost all countries, SFM is characterized as covering a very broad set of values and benefits and being tied to the concept of sustainable development. Thus, SFM goes far beyond traditional timber management in its intent and implications.

Global convergence in SFM thinking is being driven by factors such as increased international trade, world summit meetings on the environment and follow-up international efforts to improve the quality of forest management, and the rapid emergence of certification as a basis for deriving forest management standards [FAO 1997a]. Notable participants in the development of SFM include the Intergovernmental Panel on Forests (under the aegis of the UN Commission on Sustainable Development) and the World Commission on Forests and Sustainable Development. The International Tropical Timber Organization (ITTO) proposed a 'Year 2000 Objective', in which producer member countries have committed themselves to having all of their internationally-traded tropical timber come from sustainably-managed forests by the year 2000.

There are many national and regional initiatives to define criteria and indicators for SFM and to determine means of assessing progress towards achieving it [FAO 1997a]. The most prominent regional initiatives include:

- the 'Helsinki Process', involving European boreal, temperate and Mediterranean forests;
- the 'Montreal Process', involving temperate and boreal forests outside Europe;
- the 'Tarapoto Proposal' for forests in the Amazon basin;
- the ITTO producer-countries initiative;
- the UNEP/FAO Dry-Zone Africa initiative for forests in sub-Saharan Africa;
- FAO/UNEP Expert Meeting for the Near East; and
- FAO/CCAD Expert Meeting on Criteria and Indicators for Sustainable Forest Management in Central America.

FAO [1997a] estimated that these initiatives cover approximately 4.6 billion ha of forest land (see Table 1.1). In addition, it is now clear in many countries that industry wants to embrace SFM as a working concept. For example, forest industries in Brazil, Canada, Ghana, Indonesia, Malaysia, and Sweden, among other countries, are developing the ways and means to find practical approaches to implement SFM.

For the purposes of this report, all proposals for improved forest management (except certification) have been grouped under the banner of SFM. We have done this because the concept of SFM, while still evolving, has been defined so far to embrace improvements in almost every aspect of forest management. Thus, approaches such as new forestry and ecosystem management, the latter of which is equally broadly defined [e.g. Grumbine 1994; Gerlach and Bengston 1994], will be considered to be within SFM.

An examination of recent reports and forest certification criteria reveal some common themes of SFM. For example, Nussbaum *et al.* [1996] listed four main principles of SFM systems:

1. Maintain sustained yields of goods and services including ecological functions.
2. Maintain biodiversity at the ecosystem (or landscape), species, and genetic levels.
3. Optimize the socio-economic impacts of forestry.
4. Develop a supportive institutional framework for SFM, including policies, skills, and research.

The Indonesian forest certification scheme [Salim *et al.* 1997] is based on the assumption that forest management is sustainable if the ecological, economic and social functions of forests are maintained. Sustainability of the three classes of functions is further detailed in a number of basic SFM principles:

(i) Sustainability of Production Functions

Sustainability of Production Functions is characterized as follows:

- Sustainability of the forest resource is supported when the production forest area is stable and secure, assuring the continuity of timber-resource-based business.
- Increased production may be possible with increased intensity of forest management practices.
- Business profitability is sustained when the production forest is able to produce financial benefits within the limits of progressive and attractive business.

(ii) Sustainability of Ecological Functions

Sustainability of Ecological Functions refers to the production forest's ability to continue functioning as a life-support system so it will guarantee the existence of unique ecosystems and germ-plasm of both flora and fauna. Therefore, sustainability of ecological functions should consist of efforts to:

- maintain ecosystem stability within the permanent forest estate so that the forest continues to function as a life-support system and centre of biodiversity; and
- maintain survival of endemic/endangered/protected species of flora and fauna.

(iii) Sustainability of Social Functions

Sustainability of Social Functions is interpreted as the condition whereby extraction of forest products does not create negative community impacts. Commercial activity should not disturb or hinder the functioning of society, nor should it disturb existing economic activities. On the other hand, the presence of a forest concession should increase community welfare, through:

- Equity: assurance of the right to live and conduct local community life in accordance with the value system and institutional norms understood by local community.
- Community Participation: the proactive involvement of the local community in deciding the direction for and transformation process to its life system.

The Canadian Standards Association (CSA) has developed a forest-oriented environmental management system based on SFM [CSA 1996]. The CSA views an SFM system as being a framework of processes and requirements designed to ensure that targeted outcomes are achieved on a defined forest area. The SFM system contains the following four components:

1. commitment to the principles of SFM on the part of the registration applicant;
2. public participation in all major elements of the management cycle;

3. a management system with specified elements: preparation, planning, implementation, measurement/assessment, and review/improvement; and
4. continual improvement.

The SFM system relies on six criteria of SFM developed by the Canadian Council of Forest Ministers [CCFM 1995]:

1. conservation of biological diversity;
2. maintenance and enhancement of forest ecosystem condition and productivity;
3. conservation of soil and water resources;
4. forest ecosystem contributions to global ecological cycles;
5. multiple benefits to society; and
6. accepting society's responsibility for sustainable development.

2.2 REGIONAL DISCUSSIONS AND LOCAL CASE STUDIES

Most of the case studies published to date are focused on some of the stand-level impacts of adopting practices consistent with SFM. The case studies are based on operational tests, controlled experiments or simulation models. None of the case studies reported here examined a comprehensive set of potential SFM measures.

Much of the effort devoted to putting the concepts of SFM into practice is just beginning, so relatively few reports describing impacts of implementing SFM have been published. We obtained as many relevant case study reports as possible, but unfortunately no case studies were found for significant forest regions such as Africa or Papua New Guinea. Since most of the case studies describe work in progress, there will undoubtedly be modifications to the existing approaches as unforeseen issues arise. This is exemplified by recent changes made in applying British Columbia's Forest Practices Code, after the costs associated with following the Code were found to be unduly high [KPMG 1997].

2.2.1 Latin America

2.2.1.1 Chimanes Forest, Bolivia

Howard *et al.* [1996] used simulation modelling to examine the financial attractiveness of four alternative silvicultural prescriptions applied to a sample area of the Chimanes Forest in Bolivia. Inventory data were collected from unharvested forest, and timber species were assigned into one of three merchantability classes based on the demand for timber of that species. Estimates were made of the number of trees per hectare by diameter class using a negative J-shaped function.

Of the four prescriptions, the first two were essentially variations of current cutting practices which generally remove all of the merchantable timber from the forest in successive harvests, with the most valuable species harvested first. Prescription No. 1 had a cutting cycle of 5 years, whereas a 10-year delay period was modelled in Prescription No. 2. The yield of both these prescriptions was set at 2.5 m^3/ha, which represents light harvests.

The third and fourth prescriptions were designed so that a wider range of species was taken in each cut and residual trees of all species were left to provide seed. A more intensive harvest was also taken in an effort to concentrate the harvest impacts on a smaller area. The yield from Prescription No. 3 was set at 6.0 m^3/ha, and a wider range of species was harvested sooner compared to Prescriptions No. 1 and No. 2. The cutting cycle was set at 10 years. In Prescription No. 4, all harvests took timber from each of the three merchantability classes. A 10-year cutting cycle was selected as the most suitable but no effort was made to generate a fixed volume yield.

The simulation period was set at 50 years, implying that there were either 5 or 10 harvest entries in each scenario. The simulation produced results on a per-hectare basis (Table 2.1) and the researchers converted these findings to apply to a typical sawmill, which uses 8400 m^3 of roundwood per year. However, many of the results from Prescription No. 1 were reported on a basis whereby two sawmills were supported - thus, Prescriptions No. 1 and No. 2 applied to the same area and allowed a comparison of the impacts of more frequent harvest entries in Prescription No. 1 (for the resulting assumed concession sizes, see row 2 of Table 2.1).

Under these assumptions, Prescription No. 1 causes the greatest amount of damage to woody vegetation - the impacts are both intensive and widely distributed. The damage from Prescriptions No. 3 and No. 4 is concentrated on a smaller area. However, if the concession size under Prescription No. 1 is halved to 16 800 ha, the amount of damage falls to 676 M m^3. In terms of long-term productivity, Prescription No. 4 leads to the largest reduction in standing commercial volume at the end of the 50-year period. However, Prescriptions No. 1 and No. 2, which focus on removing the most commercially valuable species first, result in the eradication of the most valuable species - especially so in the case of Prescription No. 1 where almost all Class 1 and Class 2 species (the two most valuable classes) disappeared.

The financial impacts, presented as net present values (NPVs), are the discounted net value of changes in gross benefits less changes in gross costs. The lowest two rows of Table 2.1 show the NPVs calculated using two real discount rates that fell within the range of real rates recorded between 1988 and 1993 - the average real rate during that period was 17.5 percent. These results show that Prescriptions No. 3 and No. 4 yield a substantially lower rate of profit than Prescriptions No. 1 and No. 2. Unfortunately, Howard *et al.* [1996] reported that Prescriptions No. 3 and No. 4 reflect what many experts are saying should be done to ensure a sustainable harvest. This implies that the impact of following sustainable practices will reduce the profit earned by logging contractors by between 35 percent and 67 percent.

Table 2.1: Results from a simulation-based analysis of the financial attractiveness of four alternative silvicultural prescriptions in the Chimanes Forest in Bolivia

Key study parameters and indicators	Prescription No. 1	Prescription No. 2	Prescription No. 3	Prescription No. 4
Merchantable yield per decade (m^3/ha)	5.0	2.5	6.0	6.0
Assumed concession size (ha)	33 600	33 600	14 000	14 000
Total volume felled (M m^3)	1 352	709	599	796
Reduction in commercial volume (%)	37	6	24	57
NPV @ 10% ($/ha)	449	334	263	204
NPV @ 20% ($/ha)	326	218	141	108

(Source: Howard *et al.* 1996)

2.2.1.2 Paragominas Region, Eastern Amazonia, Brazil

A consistent theme of improved forestry practices in the tropics is that substantial and sustainable wood-yield gains are possible if there is an improved level of harvest planning. For example, Barreto *et al.* [1993] reported that a period of 75-100 years is required after an unplanned harvest before the forest in eastern Amazonia will return to the pre-harvest condition. In contrast, the interval can be shortened to 30-40 years with careful planning and the adoption of careful logging practices designed to minimize damage in the residual stand [Johns *et al.* 1996]. Winkler [1997] echoed this observation: “the traditional logging system as generally used in the Amazon-region in Brazil can be described as insufficiently planned, haphazard timber harvesting without any considerations concerning future crop and forest sustainability in general”. A study by Johns *et al.* [1996] showed that approximately one-third of the trees felled in a particular traditional operation were left behind in the forest, due to lack of communication between tree fellers and tractor operators.

Logging in Brazil is “usually done carelessly and, although the harvest is selective, with only a few trees removed per hectare, logged forests are often left in a highly degraded state” [Johns *et al.* 1996]. Johns *et al.* [1996] undertook a study to compare the amount of logging damage during planned and unplanned logging operations in the eastern Amazon, and to examine the economic implications. Careful logging was characterized as follows: (a) preliminary vine cutting took place two years before harvest; (b) extra care was taken during felling to reduce damage to regeneration; and (c) skid trails, log landings and extraction roads were carefully designed and pre-flagged to reduce the coverage of ground area and minimize associated damage.

Table 2.2: Comparison of logging damage and its economic implications during planned and unplanned logging operations in the eastern Amazon

Measures of harvest intensity, damage, and economic return	Unplanned logging	Planned logging
Volume removed (m^3/ha)	30	37
Canopy reduction caused by logging (%)	19	10
Residual trees damaged (No. trees/tree removed)	28.7	20.5
Ground area affected (m^2/per tree extracted)*	488	336
Residual commercial volume damaged (m^3/per tree extracted)*	10.3	5.9
NPV ($/ha)	348	467

(Source: Johns *et al.* 1996)

Note: Ground area affected is compared for planned and unplanned bulldozer operations. Planned skidder operations affected 370 m^2/tree harvested and damaged 5.7 m^3 of commercial volume per tree extracted.

Degree of damage in the unplanned logging affected more trees and tended to be more severe per tree damaged (Table 2.2). The most cost-effective planning measure was training sawyers to use directional felling techniques. The next most effective method of reducing logging impact was climber cutting, which cost $ 13.50/ha.[2] The total cost of improved planning was estimated to be $ 72/ha. However, improved planning and logging methods resulted in a net gain in profit because the efficiency of the logging operation was improved and the amount of wasted timber and commercial timber inadvertently left in the bush was reduced. Over the longer term, more timber can be harvested from the planned areas than the unplanned areas due to the reduction in damage to the residual stand and the consequent shortening of the cutting cycle. When all of these factors are taken into account, the NPV of commercial logging is $ 467/ha (presumably US$) after 30 years (at 8 percent real discount rate) compared with $ 348/ha under unplanned conditions. Thus, the NPV is 34 percent greater when planned logging and harvesting operations are implemented.

The management practices tested by Johns *et al.* [1996] were similar to those applied in the "F2M (Fazenda Dois Mil) forest management project" of Precious Woods Ltd. [Winkler 1997]. This project, started in 1993 near Manaus, Amazonas, was intended to confirm that SFM in the tropics was economically viable. Winkler [1997] listed the improved practices in the F2M project as including:

- selection harvesting of 65 tree species of commercial interest;
- selection harvesting of approximately 35-40 m^3/ha (about a half of the average harvestable volume of commercial species per hectare found for the entire F2M forest area);
- selection harvesting of mature trees with a diameter at breast height of > 50 cm;
- low-impact extraction operations to minimize damage to residual stands;

[2] Verissimo *et al.* [1992] reported that pre-harvest stand inventory cost US$ 20/ha, pre-harvest vine cutting costs US$ 25/ha, and post-harvest thinnings cost US$ 45/ha in the Paragominas region.

- application of silvicultural treatments to stimulate tree growth of commercial tree species;
- harvesting cycle of 25 years; and
- monitoring system of permanent sample plots for growth and yield assessment and evaluation of damage to the remaining stands as well as for research purposes.

Climber cutting is done in advance of harvesting as required. In addition, Precious Woods usually sets aside one-third of a logging chance as a preservation forest area, in which no logging is undertaken. Costs associated with careful logging are 12.3 percent higher than those associated with the traditional approach, but the level of profit was not calculated (Table 2.3). However, it is anticipated that use of environmentally sound practices will allow harvesters to return for a subsequent harvest in 25 years. Thus the NPV of environmentally friendly logging may well be higher than that of traditional logging, as found by Johns *et al.* [1996].

Table 2.3: Results from the F2M project in Brazil

Harvest parameters	Traditional logging	Sustainable logging
Volume removed (m^3/ha)*	92.7	36.5
Residual commercial trees damaged (% present before harvest)	52.4	28.3
Ground area affected (m^2/ha)	277.1	112.5
Losses of felled merchantable wood due to damage (% total merch. volume felled)	8.5	3.9
Actual production cost (%)	112.3	100
Harvest productivity (m^3/hr)	18.90	20.02

(Source: Winkler 1997)

2.2.1.3 CELOS Management System, Suriname

The CELOS management system was developed by the Government of Suriname after it became evident that success of converting natural forest to plantation areas was lower than anticipated. The CELOS management system is divided into two parts: the CELOS Harvesting System and the CELOS Silvicultural System [FAO 1993]. The main purpose of the CELOS Harvesting System (CHS) is to reduce site and residual-stand damage by strict control of logging operations. The main features of the CHS are:

- full inventory of exploitable trees;
- preparation of a compartment plan indicating trees to be felled, skid trails, and landings;
- use of directional felling;
- winching logs as far as possible to limit the area of machine traffic;
- hauling trees on permanent secondary roads which are re-used for subsequent harvests; and
- numbering logs for strict volume control.

The harvest volume is generally limited to 20-30 m^3/ha. The use of the CHS has reduced the area of site disturbance to less than 15 percent of total area, compared with more than 25 percent using traditional methods.

The CELOS Silvicultural System (CSS) evolved after much experimentation. FAO [1993] listed the main activities as being three post-harvest thinnings conducted 1, 8, and 17 years after the first harvest. The second commercial harvest entry can be made 20 years after the previous one. In contrast, delay times of 60 to 80 years are experienced after conventional operations. One of the main benefits of the CSS is that growth rates averaged 2.0 m^3/ha/yr versus 0.2 m^3/ha/yr on control plots that were harvested using conventional methods and then left to re-grow on their own. The success of this system has led to its adaptation and application elsewhere in Central and South America. The Paracou project in Guyana and a trial at Manaus in Brazil have yielded similar results [FAO 1993].

2.2.1.4 La Tirimbina and Villa Mills, Costa Rica

Quiros *et al.* [1996] reported that the lack of planning and control of timber harvests in the majority of Central American countries constitutes activity that works against the principles of sustainability. CATIE (Tropical Agricultural Research and Higher Education Center) is one of many organizations trying to develop RIL techniques. The technical aspects involved in RIL can be divided into three phases: pre-harvesting; harvesting; and post-harvesting [Quiros *et al.* 1996]. Each phase includes the following activities:

Pre-harvesting:

- preliminary forest inventory of the management unit (costing US$ 27/ha);
- general management plan;
- planning inventory of the harvesting unit;
- harvesting plan;
- workforce training.

Harvesting:

- construction of forest roads (US$ 10 000/km for primary roads, US$ 500/km for secondary roads);
- directional tree felling;
- skidding;
- bucking, loading and transport operations;
- control.

Post-harvesting:

- harvest of residual logs;
- maintenance operations.

Few numeric data were presented by Quiros *et al.* [1996]. Additional costs were cited for two of the activities listed above, but it is not clear how these compare with the harvest cost of conventional operations or the value of timber harvested. It appeared that the added costs were at least partially offset by productivity gains. Quiros *et al.* [1996] reported that many logs are left unextracted after timber harvest due to difficult access or because they are split, twisted or too small. In La Tirimbina, Costa Rica, unextracted logs with a volume equivalent to 20 percent of the extracted log volume were sawn on-site, with the products being used for home consumption or sold on the local market.

2.2.2 Southeast Asia

Southeast Asian countries have been active in making efforts to modify timber-harvesting practices in line with SFM [Ghazali and Simula 1996; FAO 1997a]. Much of the effort has focused on improvements to practices, increased planning, and skills upgrading for local timber harvesters. Economic data are difficult to obtain regarding impacts of operational tests in SFM. Ghazali and Simula [1994] estimated that the average cost of implementing SFM in the tropics was US$ 38 to US$ 60 per hectare, although there is potential for at least some of this cost to be offset by productivity gains [Nussbaum *et al.* 1996].

2.2.2.1 SFM in Sarawak, Malaysia

The state of Sarawak, East Malaysia, experienced a boom in timber harvesting during the 1980s that drove the annual harvest level up as high as 18 million m^3, which was well above the level thought to be sustainable (i.e. 10 million m^3/yr). The Sarawak Government invited the ITTO to review the forest management system in the state and make recommendations that would lead to the development of a SFM programme.

The ITTO made recommendations that touched on everything from government staff levels to royalty rates to measures for controlling forestry activities [ITTO 1996]. A key recommendation was that the harvest volume be reduced by 50 percent from the peak to 9.2 million m^3/yr, a level deemed sustainable. The ITTO also recommended that a biodiversity conservation area of more than 180 000 ha be established, which is equivalent to 0.26 percent of the planned gazetted Permanent Forest Estate area of 6.77 million ha [ITTO 1996].

2.2.2.2 Reduced-Impact Logging, Sabah, Malaysia

Conventional logging practices in Malaysia cause severe damage to sites and residual timber. Moura-Costa and Tay [1997] reported that in typical logging operations which remove 8-10 trees per hectare, as much as 50 percent of the remaining stock is damaged and up to 40 percent of the site is traversed by heavy machinery. Experience elsewhere has shown that undertaking some relatively straightforward measures can substantially reduce such negative impacts of logging operations. A cooperative venture was organized between Innoprise Corporation Sdn. Bhd., a semi-government organization that has logging concessions in Sabah, and the New England Power Company to adapt and apply impact-reduction techniques including undertaking detailed pre-harvest planning, using directional felling, cutting climbers before logging, and training staff and logging operators. The test logging operations were undertaken between 1992 and 1995 on 1400 ha and an independent impact assessment was performed to compare the results of traditional logging with the reduced impact logging (RIL) methods [Moura-Costa and Tay 1997]. When a harvest volume of 120 m^3/ha was removed, the use of the RIL system led to substantial reductions in logging damage, as defined by proportion of harvest block traversed and damage to residual trees (Table 2.4). Due to restrictions on logging steep slopes, the harvest volume was reduced under the RIL system.

Table 2.4: Post-logging impacts using conventional and RIL systems

Impact indicator	Conventional systems	Reduced-impact logging
Roads (% logged area)	3.3	1.6
Skid trails (% logged area)	13	4
Log landings (m^2/ha)	103	57
Trees damaged (%)	56	29

(Source: Moura-Costa and Tay 1997)

While a full economic analysis has not yet been completed, preliminary figures show that the costs of logging increased by US$ 5/m^3, which corresponds to 5 percent of the price of logs in the mill yard. When compared to the final cost of wood on a retailer's shelf in Europe, these additional costs amount to 0.04 percent of the product price. Extra costs were required to provide more detailed inventories, training, climber cutting, and intensive supervision.

The entire project cost US$ 450 000 [Moura-Costa 1996], and based on an average harvest volume of 120 m^3/ha from each of the 1400 ha treated, the cost per cubic metre is US$ 2.68. Additional gains in the form of longer-term increases in productivity can be expected as a result of adopting more environmentally sensitive measures.

2.2.2.3 Tropical Forestry Action Plan, Indonesia

One of the centre-pieces of the new Tropical Forestry Action Plan developed by the Indonesian Ministry of Forestry is a shift to a longer cutting cycle, which will reduce the annual harvest from 38 million m^3 to 31 million m^3, a reduction of 18.4 percent [D'Silva and Appanah 1993]. The lower figure is believed to be close to the long-run sustainable harvest volume.

Putz and Ashton [1992] recommended that a 60- to 70-year shelterwood system replace the selection felling system where site and forest characteristics permit. This system can be more cost-effective than selection cutting. The Indonesian Ministry of Forestry has acknowledged that shelterwood may be appropriate for much of the country's forests.

In addition to productivity gains from use of the shelterwood system, the residual forest will likely be more fire resistant than the forest left behind after selection logging. In 1982, tens of thousands of hectares of selection-logged forest caught fire in East Kalimantan [Peters 1991], much of which converted to lalang (*Imperata* spp.).

2.2.2.4 The STREK Project, East Kalimantan, Indonesia

The STREK Project (Silvicultural Techniques for the Regeneration of logged over forest in East Kalimantan) was intended to develop management rules supporting sustained productivity of the East Kalimantan forests [Sist and Bertault 1996]. One of the recommendations was that harvest volume be limited to 80 m^3/ha. On the nine study plots, average harvest volume was 87 m^3/ha. Thus, a reduction of 9 percent in harvest volume is advocated. This contrasts with a standing pre-harvest volume of 402 m^3/ha, of which 60 percent was in Dipterocarp species (the major commercial species).

The use of improved forest management techniques is expected to improve the longer-term productivity of the forest. Two years after logging, the plots harvested with the reduced-impact techniques showed a net volume gain of 1.5 m^3/ha whereas those harvested with conventional measures showed a net gain of only 0.7 m^3/ha. Fifteen years after logging, the treated plots showed a net gain of 4.3 m^3/ha whereas the untreated areas showed a gain of only 1.6 m^3/ha [Sist and Bertault 1996]. Thus, the longer-term increase in volume growth ranges from 50 percent to 270 percent.

2.2.3 Russia

The future of Russian forests is of global concern, for they comprise more than one-fifth of the total area of the world’s forests [Strakhov 1997]. Discussions are ongoing within the Russian and international forest community about how to achieve SFM in the Federation [e.g. Nilsson 1997a; 1997b]. The questions being addressed range across ecological [e.g. Duinker 1996b], economic [e.g. Backman 1996] and social [e.g. Granåsen et al. 1997] themes, thus forming a comprehensive look at sustainable development of the forests and forest sector.

The relationships between SFM and Russia’s wood supply are probably unique in the world, for at this time Russia’s forests are significantly underused for fibre supply [Backman 1996]. From an ecological viewpoint this may be deemed favourable, because recent and contemporary Russian forest-management practices leave much to be desired [Shvidenko and Nilsson 1994]. Earlier discussions about how to revive Russian forest management so that even the customary regimes can be implemented, and thus contribute to a recovery of the flagging national economy, are giving way to debates about whether contemporary regimes, as laid out in Russian forestry handbooks, are appropriate for 21st-century forest management. For example, Shutov [1995] claimed that “Russia’s foresters are of the widespread opinion that for many conditions partial cuttings . . . more closely mimic natural disturbances.”

Implementation of SFM in Russia faces many obstacles. Technology for timber harvest and silvicultural treatments is outdated, investment financing is scarce because of political instabilities, institutions and policies are ill-suited to the new economic and political circumstances, and corruption and confusion (in addition to lethargic bureaucracies) are said to be widespread in the forest sector. In the event that Russians are able to overcome the obstacles and bring about the much-needed revival of its forest sector, we are optimistic that Russia will move toward fulfilment of its commitments to international environmental agreements related to SFM. This, of course, will also depend on satisfactory redevelopment of Russia’s domestic forest policies [Duinker 1997; Nilsson 1997c].

2.2.4 Europe

2.2.4.1 Nordic Countries

Forest management in the Nordic countries is turning towards ecosystem management. A good example of this is the recently developed forestry environmental guidelines [Department of Forest Policy, Ministry of Agriculture and Forestry 1994] developed by the Finnish Government. The guidelines recognized that past forest management was decidedly timber-oriented, and required change. The document stressed two approaches to the focus on forest ecosystems. One is the protection of forest ecosystems in parks and reserves. Current programmes are strong but require improved network design as well as the addition of old growth, habitats of endangered species, scenic areas, and heritage biotopes.

The second approach is a move from timber management to nature management [Department of Forest Policy, Ministry of Agriculture and Forestry 1994]. Wood production and biodiversity conservation are seen to be fully compatible. Management shifts include: (a) focus on special management for key biotopes; (b) focus on naturalness (despite protection against potential damaging agents); (c) leaving live trees and snags standing in clearcuts; (d) light site preparation; (e) careful old-field afforestation; (f) mixed-species stands; (g) avoiding excessive cleaning during harvest operations; (h) reduced use of herbicides; (i) more care in fertilizer application; (j) no new (virgin) drainage works; (k) biodiversity considerations in road layout; (l) reducing harvest-related damage to ecosystems; (m) softening the impact of timber management on the eye; and (n) pressure for reductions in regional air pollution.

In Swedish forest management, biodiversity conservation is being given equal importance with timber production [Lämås and Fries 1995; AssiDomän 1996; National Board of Forestry, Sweden 1996]. The new forest policy [Skogsstyrelsen 1994a], which is backed up by a new forest act [Skogsstyrelsen 1994b], speaks of preservation of the productivity of forest land, and the maintenance of natural levels of biodiversity where all indigenous plant and animal species can survive in vigorous populations. The overall strategy is one of multiple use, where each hectare of forest land, in principle, must contribute to both timber production and environmental goals [Skogsstyrelsen 1994a]. The pursuit of biodiversity conservation is not based solely on forest reserves (i.e. where timber harvest is forbidden), partly because so much of the Swedish forest has already been managed intensively for timber [Lämås and Fries 1995], and partly because substantial increases in reserve area will harm the Swedish economy [Skogsstyrelsen 1994a]. Thus, biodiversity conservation must be pursued within the context of continued management of forests for timber production. The new Swedish approaches to forest ecosystem management are described below as separate stand-level and forest-level specifications of silviculture and forest-management regimes.

Modified Stand Management

Fries *et al.* [1997] offered the working hypothesis that a combination of reserves (protected areas) and modified management of the timber-producing forest is the best approach for conserving forest biodiversity in Sweden. They stated that the biggest needs are: (a) use of fire in silviculture; (b) maintenance of old growth; (c) protection of coarse woody debris; and (d) raising the deciduous composition of stands. They offered three modified management regimes for (a) Scots pine stands on dry and mesic sites; (b) Norway spruce or deciduous-dominated stands on mesic sites; and (c) long-continuity Norway spruce stands.

Ecolabelling Criteria

The Swedish Society for Nature Conservation and World Wide Fund for Nature Sweden [SSNC/WWF 1995] developed a set of "Preliminary Criteria for Environmental Certification of Swedish Forestry". The main focus of the programme is conservation of forest biodiversity. The organizations encouraged forest owners to view the increased costs of changing their forest management as investments, not as operating costs. There were 21 criteria that focus on habitat maintenance, retention of deciduous trees and snags, avoidance of pesticides and fertilizers, and more-detailed planning. The forest industry response was mildly favourable but industry felt that a number of issues had to be discussed further. It was also recognized that the effort would have much more credibility if it were undertaken jointly with other Nordic countries. As a result, Sweden joined Norway and Finland to develop a set of Nordic forest certification standards [Ghazali and Simula 1996]. The conceptual design for the process has been developed based on international agreements and principles of sustainable forestry. At this time of writing, the latest development in Sweden is an announced agreement in mid-June 1997, among members of the Swedish national working group on certification, on a draft national standard based on the Forest Stewardship Council's principles and criteria [Forest Stewardship Council 1997].

The ASIO Approach

Rülcker *et al.* [1994] proposed a strategy for biodiversity conservation and otherwise ecologically sound forest management based on mimicking fire. In summary, for the boreal forest, all sites/stands are classified into one of four classes. Sites are initially classified on the basis of moisture regime: wet, moist, fresh and dry. Subsequently, their designation is adjusted based on vegetation type, topography, mosaic and location. The classes are defined by fire frequency and intensity, as follows:

- A - Almost never catches fire.
- S - Seldom catches fire (return interval roughly 200 years).
- I - Infrequently catches fire (return interval roughly 100 years).
- O - Often catches fire (return interval roughly 50 years).

The Rülcker *et al.* [1994] paper described typical conditions in each class, and provided broad suggestions for the types of stand management regimes that should be applied once a site has been classified into the ASIO system.

Forest Landscape Management - Stora Skog

In addition to describing biodiversity-enhancing stand-level treatments in its corporate publications, Stora Skog [1994a; 1994b; undated] has been promoting its new landscape-based approach to forest management. The company's overall goal is as follows: "the aim of our forestry operations is to contribute towards the achievement of Stora's financial objectives, and to secure a high, valuable and sustainable yield of forest produce whilst maintaining the biodiversity of the forest land” [Stora Skog 1994a]. Alongside sustained-yield timber production, which the company claims to have practised for a long time, Stora Skog declared that it must now sustain biodiversity, interpreted as the “species richness of plants, fungi and animals” [Stora Skog 1994b]. The company’s strategy is to “restore natural forest qualities in the managed forest landscape”, and its aim is “to again disperse today’s pushed-back animals and plants over a larger part of the forest landscape” [Stora Skog 1994b]. It is trying to use timber-harvest techniques to match patterns produced by natural disturbances. It recognizes that uniformity through timber production was wrong, and is attempting to restore a natural-like variation within/among forest stands.

Evolving Forestry - MoDo Skog

MoDo Skog [undated] is the third largest private forest landowner in Sweden. The company is modifying its forest-management regimes, in pursuit of biodiversity conservation, by trying to emulate natural patterns and processes. The new regimes, consistent with the general directions discussed above, include: (a) “gentle methods in the most sensitive forests”; (b) more use of natural regeneration; (c) increasing the proportion of older trees in the forest; (d) generous buffer zones around water bodies and wet areas; (e) creating more dead wood on the forest floor; (f) preserving cultural features of the forest; (g) more use of prescribed burning; (h) increasing the proportion of deciduous trees; (i) discontinuing timber felling in mountainous areas; and (j) making clearcuts smaller and less clean-shaven [MoDo Skog, undated]. Like Stora Skog, MoDo Skog believes that traditional high wood production can be continued while adjusting forest management to conserve biodiversity.

Summary of Impacts

A number of Scandinavian organizations and companies are adopting SFM practices which are consistent with those described above in the North American case studies. No estimates of cost or harvest volume impacts were cited in the references above. The additional planning requirements seem likely to impose added costs consistent with those experienced in North America. Discussion with one expert indicated that there would be little added cost as a result of leaving residual deciduous trees and snags [R.E. Pulkki, 1997, personal communication]. However, some impact on wood supply has been experienced. Mr. A. Berklund is quoted in Kungl. Skogs-och Lantbrucksakademiens [1996] as saying that the recent shift to increase biodiversity has resulted in a 6-8 percent reduction in wood supply.

2.2.4.2 Austria

Most European forests have been heavily influenced by humans for periods ranging from centuries to millennia. Wetlands have been drained, forest structures have been simplified, fire has been severely curtailed, wildlife populations have been greatly modified, and most forests have experienced some degree of timber harvest. Given repeated interventions of many types, it is clear that present forests are significantly different from the ‘original’ forest ecosystem in most of Europe. The major issue is to what degree the forest should be restored. In many cases, the social and environmental costs of the restoration process may simply be too high to warrant the necessary actions. For example, required measures may include the flooding of land, the use of pesticides, or the removal of existing forests which are non-native.

However, in spite of these difficulties, there are some types of management actions which will form part of most applications of ecosystem management. They include:

- Finding ways to re-connect fragmented forest areas.
- Identifying ecosystem types that are threatened and preserving them.
- Applying restoration ecology principles where required.
- Increasing plant and animal diversity at both the landscape and site levels in most forest areas.
- Matching tree harvesting practices to the natural developmental characteristics of the forest.
- Leaving more coarse organic debris on forest sites.
- Continuing to apply mitigative factors to reduce the influence of human pollutants.
- Allowing a portion of standing volume to be depleted by natural losses.
- Restricting grazing to allow natural forest regeneration.

There are many complex socio-cultural issues in the European context. The public perception of desirable forests has been influenced by the high degree of forest modification which may make it difficult for the public to accept widespread changes back to more natural conditions. It is difficult to generalize across Europe since, between nations, there are frequently different attitudes towards forests. This section describes how one European country, Austria, is grappling with the development and application of SFM.

Located in Central Europe, two-thirds of Austria's territory lies within the Eastern Alps. Altitude, slope, and aspect, which affect climate, and topography and geology are the dominant site factors and give rise to an enormous variety of different forest ecosystems. Coniferous forests are mainly found in mountain regions, pure deciduous forests dominate the plains, and mixed forests inhabit transition areas. Riparian forests occur in river basins and along rivers with regular flooding.

Some 36 percent of Austria's land area, or 3.331 million ha, is classed as exploitable forest [BMLF 1994]. This forest has an average annual increment of 9.4 m^3/ha, which is well above the average annual harvest level of 5.9 m^3/ha [BMLF 1995a]. This results in an increase of growing stock of 1.2 percent annually which could support a significantly higher timber harvesting rate. Economically exploited forests most commonly consist of Norway spruce with a share of 56 percent of the forest land area, followed by beech (9 percent), various pine species (6 percent), larch (*Larix decidua*) (5 percent) as well as white fir (*Abies alba*) and oak (*Quercus*) species [BMLF 1995b].

In the Eastern Alps, significant human influence on the forest can be traced back 800 years, while in the climatically more favourable Southern and Central Alps this influence can be dated back 4000 years. As early as the Middle Ages, forest regulations were enacted to maintain forests. In 1852 the Imperial Forest Law was introduced to enforce the concept of sustainability [BMLF 1995a]. Today, social demands on the forest are high, particularly because of the range of values produced. As new impacts such as tourism or forest decline cannot fully be solved by this century-old concept of multiple use, instruments have been introduced to coordinate and secure the multiple use of forests, including a National

Environmental Plan, an Austrian forest development plan, a danger zone map, a natural forest reserve network, and a programme for maintaining the genetic variety of forest trees.

The National Environmental Plan [Österreichische Bundesregierung 1995] is a strategic paper aimed at environmental security and improving the quality of human life and well-being. It lists internal and external factors which diminish the condition and the functions of forests, and endanger its stability. In contrast, the Austrian forest development plan is a 10-year planning framework describing actual forest conditions, pointing out key functions and assisting in the optimal sustainable maintenance of the functions of the forest. All the forest land is inventoried, assessed for values, and mapped. The forest is divided into 17 000 areas for which a primary use is assigned. The primary function receives the highest priority in the respective forest area. For each of these 17 000 function areas, the justification of the selected valuation is recorded and plans set out for necessary measures according to their priority and time frame.

The danger zone map is a basic document for land development and is particularly useful for ecosystem management in watersheds. A combination of management by technical construction and biological forest measures is intended to result in a more stable forest which will enhance protection against floods and avalanches. Primary measures include reforestation at high altitudes, the improvement of protection forests, and technical constructions for flood and avalanche control.

The Austrian natural forest reserve network is intended to represent all types of forest found in Austria for the purpose of conserving biodiversity and permitting research and teaching. So far, it includes some 3000 ha of relict virgin old-growth forests and original forests which were not exploited in former times. In contrast, the programme for maintaining the genetic variety of forest trees aims to preserve the genetic resources of forest tree populations through selection and care of gene reserves, long-term storage of forest seeds, and installation of seed plantations.

In the past, forest management favoured profitable coniferous species and the use of economically efficient methods such as clearcuts and widespread planting of spruce and pine. Current Austrian forest policy is intended to reverse this trend by relying more on natural reforestation and ecologically adapted silviculture. The share of deciduous and mixed forest stands now amounts to 42 percent, a 27 percent increase since the 1970s. While artificial regeneration occurs on only 2 percent of the total forest land area, natural regeneration already covers 15 percent but contributes 87 percent to all forest regeneration [BMLF 1994].

To achieve such changes, single-stem harvest operations have increased by 8 percent during the last decade, while the clearcut area decreased by 20 percent. Still, clearcutting accounts for 47 percent of timber harvesting. To a certain degree, the mountainous topography of Austria limits the application of single-stem, shelterwood and partial harvests. Clearcuts exceeding 0.5 ha require official permission and are prohibited in excess of 2 ha. This is why clearcutting results in a diverse mosaic of even-aged patches of forest stands.

Many initiatives have been undertaken to help return forests to a more diverse state. One of these is an ecopoint model which assigns points to a forest for its tree species composition, structure and texture, the share of natural regeneration, and presence of structural features such as small biotopes, old-growth stands, dead trees or rare tree and shrub species [Maier 1995]. The scoring system is guided by the prevailing understanding among forest experts that uneven-aged and mixed forests have a higher ecological value than even-aged, single-species stands. This model will eventually be used to restructure forests with the help of ecopoint-related subsidies.

Within Austria, there is an ongoing discussion of "Naturnahe Forstwirtschaft", or nature-oriented forest management, an approach seen to be critical in conserving forest biodiversity [Federal Ministry of Agriculture and Forestry, Austria 1996]. Although Austria's forests are a cultivated landscape resulting from centuries of human care and attention, it is recognized that intensively used forests are rich in biodiversity and therefore subject to maintenance as demanded by law. Pro Silva Austria [1995], a regional association of nature-oriented forest experts, felt that forest management must adhere to the following principles to achieve ecological and economical sustainability:

- no clearcutting;
- balance in increment and harvest;
- regular timber harvests of low yield; and
- tending and harvesting decisions made on the basis of individual stem characteristics.

Pro Silva Austria [1995] advocated that economic sustainability can be achieved by producing large-dimensional and high-value timber by means of selected thinning and tending during all stages of development; natural forest regeneration in long regeneration periods; and increasing the stability of forest stands by increased management of single stems [Pro Silva Austria 1995]. National aspects of SFM have been linked to international indicators through the Forest Stewardship Council [1996].

2.2.5 North America

2.2.5.1 White River Forest, Ontario, Canada

The dynamics of the North American boreal forest are driven by large-scale disturbance, with fire and spruce budworm being the most important disturbance agents [Baskerville 1995]. In the absence of fire suppression, average fire return times in some regions are as short as 60 years. However, they are now much longer because fire suppression has been quite effective since World War II. Efforts to control spruce budworm by aerial application of DDT were initiated in the 1950s. The prohibition of DDT use in the 1970s is implicated as a partial cause of some of the large outbreaks shortly afterwards. More recently, the use of *Bacillus thuringiensis* (Bt) has been refined and managers now feel that they can control spruce budworm effectively. Fire and insect pest suppression is having a profound impact on the nature of the forest, especially on the age-class structure and stand composition. Thus, one of the main intents of ecosystem management in the boreal forest is to try to use timber harvesting to mimic the natural disturbance pattern to a degree that is both socially acceptable and ecologically defensible [Hunter 1993; Miller and Rusnock 1993].

The Ontario Ministry of Natural Resources (OMNR) and Domtar Inc., co-managers of the White River Forest Management Area in Ontario, have devised a management plan for the forest based on SFM principles. We consider this to be a reasonable initial model for boreal applications of SFM.

Fire is the mostly strongly controlled natural disturbance factor, so mimicking natural fire patterns formed many of the new management guidelines. Ecosystem abundance is to be monitored using 1000 km^2 blocks, which is based on the size of ecological zones within the forest and the order of magnitude of historical fires. Average fire return times were estimated at 75-125 years [Eason 1993], with few areas experiencing more than 200 years without fire.

The underlying objective of the plan is to conserve or maintain forest biodiversity [Eason 1993]. Management is not intended to maximize biodiversity, but rather to provide a range of diversity across the forest landscape. The management plan approaches this task by considering a much wider range of wildlife species than is usually considered and applying both coarse and fine filters. Wildlife populations are allowed to fluctuate around present levels within pre-determined ranges, reflecting the disturbance-oriented nature of the forest and the attendant wide fluctuations in species populations over time.

Recently, most boreal forests have been managed using featured species guidelines, which are a prime example of a fine-filter approach. The difficulty with using only the fine-filter approach is that many species with habitat requirements differing from those of the featured species may be put at risk since their welfare is not part of the structure of management goals. A complementary approach is the coarse filter, which helps ensure that all ecosystem types are represented in the forest and thereby ensure that the species dependent on each ecosystem type will be retained. Most biologists think that a combination of fine and coarse filters will be appropriate in most situations. The coarse filter looks after many of the smaller organisms while the fine filter focuses on larger organisms that require a mixture of habitats.

The coarse filter proposed for the White River Forest uses forest ecosystem classification (FEC) type, age, and stocking characteristics of forest areas to define ecosystem types. For example, the management plan stipulates that no FEC type should increase or decrease by more than 50 percent from the baseline area, which was set on the basis of pre-harvest inventory data. This will allow cover type abundance to fluctuate over time as would occur after large fires, yet it prevents the long-term decline of any single cover type.

Guidelines were also developed for forest age structure. In each 1000 km^2 block, 25 percent of each FEC type is to be older than the estimated fire rotation age and, within each 100 km^2 block, 12.5 percent of similar FEC types should be older than the fire rotation age. This approximates the average frequency of older stands in a forest subject to a natural fire regime. Guidelines were also developed for stand density. This example illustrates how different spatial scales are recognized within the management unit.

At the stand level, measures were also taken to improve the resemblance of cutover sites to burn sites and increase the area of standing dead forest, the habitat type considered to be most reduced by previous forest management practices. These include leaving snags, leaving live trees and patches to provide dead trees in the future, increasing the use of prescribed burning, and limiting salvage activities. A procedure is being developed to allow natural fires to burn in unmerchantable areas under safe conditions. The retention of white-spruce seed trees is emphasized to maintain the species and provide supercanopy wildlife habitat structure.

Measures have also been taken to use a wider range of harvest block sizes (cuts average about 1 km^2 but range from 0.5 km^2 to 5 km^2), to orient them with the prevailing winds, and to organize harvesting schedules so as to maintain large leave blocks for extended time periods. The idea is to create a range of cut patterns similar to natural fire patterns to maintain habitat for both area- and edge-sensitive species as well as edge-dependent ones.

The expected impact of these measures is to reduce the wood supply volume by roughly 25 percent from the theoretical maximum, largely due to retention of older stand types. Reserves and by-pass areas already reduce the harvest by 15 percent from the theoretical limit. Much reserve and by-pass area is in older age classes, so mimicking the natural age structure reduces the harvest by about 10 percent. While the full impact of these measures on harvest costs is unknown, the inclusion of large harvest areas and the increased concentration of harvest activity were favoured by Domtar.

These findings correlate well with results of a simulation modelling study done on the 270 000 ha Seine River Forest in Northwestern Ontario. Forest management is presently characterized by exclusive use of clearcutting followed by site preparation, planting, and tending. Gooding [1997] used a simulation model to compare this approach with an alternative approach using partial harvesting. Two main scenarios were run: Option A - maximum sustainable harvest using clearcutting only; and Option B - maximum sustainable harvest obtainable using partial harvesting prescriptions applied under ecosystem management principles. Option B also featured increased use of intermediate harvests and natural regeneration, and an extensive permanent road network [Wedeles *et al.* 1995].

Over a 200-year planning horizon, adoption of the alternative timber-harvesting methods reduced the annual allowable cut from 313 000 m^3 in Option A to 238 000 m^3 in B. This represents a 24 percent reduction in wood supply. In contrast, the area cut annually in Option B was 3600 ha compared to 2300 ha under Option A; as well, patch sizes were smaller with Option B. Under Option B, forestry activities were dispersed across the landscape, which may create more land-use conflicts with other forest users. Option B also resulted in higher total forest operating costs (i.e. harvest, transport and silvicultural costs) compared to Option A. A greater reliance upon thinning to supply wood from small-diameter trees will increase wood costs. However, total silvicultural costs fell as the need for planting declined.

Summary of Wood Supply Impacts

With the implementation of SFM, Domtar Inc. expects that the wood supply will be 25 percent lower than the theoretical maximum. Measures already in place (e.g. reserves around raptor nests, heronries, moose calving areas, wildlife movement corridors) have reduced the timber harvest by 15 percent. An additional 10 percent reduction will arise from retention of older stands.

2.2.5.2 Haliburton Forest and Wildlife Reserve, Ontario, Canada

The deciduous forests of southern Ontario and northeastern United States lend themselves to management for both biodiversity and high-value forest products. Silvicultural systems traditionally used for wood production can be readily modified to enhance biodiversity. For example, conventional clearcuts can be modified to include scattered residual trees (both living and dead) for highly exposed perches and cavity users. Low-density thinnings and open shelterwoods are designed to promote development of understory vegetation and lead to the regeneration of tree species of intermediate shade tolerance. Irregular shelterwood and selection harvests provide permanent vertical structure, especially if some large trees are retained. Areas disturbed during logging (such as skid trails, landings, and roadsides) can be maintained semi-permanently in early successional grass or forb communities [Barrett 1995]. Overall, the application of ecosystem management will emphasize the protection of advanced regeneration during timber-harvest operations and reduce the use of artificial regeneration practices [Irland and Maass 1994].

The Haliburton Forest and Wildlife Reserve, a non-industrial private forest of 20 000 ha, is located in the eastern hardwood forest of North America, some 150 km northeast of Toronto. It had a long history of high-grade logging up to the 1960s, when the commercial timber supply was finally exhausted. The present owner has set two primary management goals:

- to restore the quality of standing timber; and
- to diversify the product range to include recreation as well as timber.

These objectives are being met through the owner's adoption of an ecosystem management approach, marked by the use of partial-cutting systems. Under ecosystem management, the average volume of wood harvested per hectare has decreased and the focus has been on removing low-quality timber. The owner has also set up a recreation and outdoor education programme which provides enough revenue to pay for the costs of upgrading the timber quality. The recreational users, including mountain bikers, campers, hunters, cross-country skiers, snowmobilers, birdwatchers, fishermen, musicians, high school and university groups and many other outdoor enthusiasts, contribute about 80 percent of the annual revenue of the operation. Combining a timber-harvest operation with a recreational programme has had implications for planning, roads, timber harvesting systems, and silviculture.

Planning has become more complex. In maintaining communication between the managers and user groups, the annual cost of planning has risen by over 200 percent. To distribute the timber-harvest operations spatially, more roads had to be built, increasing the average annual cost of road construction by 300 percent. The cost of keeping more road active has meant an increase in maintenance cost of at least 100 percent. Since the roads are multi-purpose, some of the costs can be allocated to recreation.

The timber-harvest system is currently a line skidder operation and there is significant experimentation with new logging techniques used in Europe. The overall emphasis is to rely on the skidders for longer skid distances and therefore build less permanent road. There is also an emphasis on minimizing soil compaction by harvesting timber only when soil is either frozen or dry. Horses are used for skidding in riparian areas where selection cutting occurs. They have a relatively low impact on soils in the logging operations. The increase in costs due to changes in the harvest operations is in the range of 100-200 percent.

The silvicultural systems promote a diversity of tree species, wildlife habitat and improvement in wood quality in the stand. The emphasis on stand diversity ensures that minor tree species can play an appropriate ecological role and provide different products for the next generation. To conserve wildlife, suitable trees are especially left for birds of prey, cavity nesters and small mammals. Trees are harvested from each stand at intervals of about 20 years. As tree quality improves on the remaining forest, an increasing proportion of wood products will be high-quality veneer logs and sawlogs, rather than firewood and low-quality sawlogs. The costs of changing to this type of silvicultural system are significant.

The increase in total wood costs ranges from 300 percent to 500 percent. This is largely attributable to higher access costs and a lower volume per hectare. Due to the unique nature of the operation, this cost increase can be absorbed since the forest provides many other direct economic benefits to the owner.

Summary of Wood Supply Impacts

- There is a short-term reduction in wood volume and quality; however, these will both rise in the longer term.
- There is an increase of 300-500 percent in total operating costs but some costs are reallocated to activities unrelated to timber harvest.

2.2.5.3 Clayoquot Sound, British Columbia, Canada

The West Coast forest region is the source of so-called new forestry, which is similar to SFM and is here treated as being synonymous with it. In the western portion of the region, a current focus is modification of traditional management practices to create the structural features of old-growth stands in relatively young second-growth stands. Several pre-commercial and commercial thinning regimes are being tested in young plantations to stimulate the rapid development of more complex structure. Desirable features include large trees, snags, coarse woody debris on the ground and multiple canopy layers [Maser 1988; Franklin 1992]. There is interest in increasing the use of uneven-aged management on the coastal species through either single-tree or group selection methods to create a fine-grained landscape pattern. Initial attempts to modify clearcutting in plantations have included reserving some mature trees throughout the next rotation to provide structure, future snags, and coarse woody debris. Extended rotations are also advocated for portions of the landbase [Barrett 1995; Curtis 1997]. The intensity of site preparation has been reduced to leave slash on the site.

In the US Pacific Northwest, harvest levels have been dramatically reduced to conserve the spotted owl (and old growth in general, for which the owl is generally deemed an indicator species). In 1995, the regional rate of harvest suggested by the US Federal Government was 1.1 billion board feet per year, (ca. 2.0 million m^3/yr) which is approximately 25 percent of the average harvest rate recorded during the 1980s. There are also increasing demands for lower rates of cutting in British Columbia. There, the provincial annual allowable harvest volume peaked at 75 million m^3 in 1990, and by 1994 it had declined to 72 million m^3 [Miller 1994].

The long-term harvest volume is expected to be approximately 55 million m^3 [Miller 1994], which would represent a fall of 27 percent from the 1990 peak.

A unique planning process was recently used in Clayoquot Sound, Vancouver Island, British Columbia. Clayoquot Sound is a most prominent symbolic battleground in the fight over preservation of old-growth forests on the West Coast. The core area consists of roughly 260 000 ha of forest, of which 160 000 ha is commercially productive. Of this, 30 000 ha has been logged, 39 000 ha is protected from logging, and the remaining 91 000 ha is commercial old-growth forest. The provincial government responded to the protests by commissioning a Scientific Panel [SPSFP 1995] to recommend how to incorporate a full range of forest values, including those of the First Nations, into forest management and retain as much old-growth character as is compatible with other objectives.

The cornerstone of the Panel's recommendations [SPSFP 1995] is to change the silvicultural system so that it embodies the principles of ecosystem management. The proposed alternative system, known as the *variable retention silvicultural system*, is a combination of seed-tree, shelterwood, selection, and clearcut-with-reserves silvicultural systems. The proposed system emphasizes the retention of variably-sized groups of trees in the managed forest to create characteristics similar to the patterns and remnant structures left after natural disturbances [SPSFP 1995].

The Panel recommended at least four significant changes to the planning system:

1. The basis of forest planning will be a hierarchical set of constraints on harvest area at different scales. For example, no more than 1 percent of the area in a watershed can be cut in any given year. Previously, the harvest level was based on a calculated sustainable harvest volume.
2. More planning will be controlled at the local level.
3. The traditional and scientific knowledge of First Nations will be integrated into objective setting and planning.
4. The planning process will use an adaptive management framework, which facilitates the development of knowledge based on the outcomes of management.

As a result of these changes, planning will be more complex. Preliminary estimates are that planning costs will increase by more than 80 percent [Thibodeau 1994].

To meet the spatial constraints imposed at different planning scales, more roads will have to be constructed in the next few harvest periods. Keeping roads active for longer will increase road maintenance costs by more than 30 percent [Nelson *et al.* 1993]. In the first two decades, the estimated increase in road development is 40 percent and total road costs are expected to increase by more than 70 percent [Nelson 1993a; Nelson *et al.* 1993]. Nelson's case studies were undertaken in natural forests which had not been completely accessed; thus, much of these additional costs represents an acceleration of road-building. Overall, the emphasis is to reduce the impacts of roads by decreasing road density and road width and by deactivating roads once timber-management activities have ceased.

The method used to yard trees (moving trees from stump to roadside) will also change. The use of skyline yarding instead of the high-lead yarding system has been recommended in steep terrain, which will increase costs by more than 20 percent [Thibodeau 1994]; there is no significant increase in costs except in areas where the volume removed exceeds 350 m^3/ha [SPSFP 1995]. In total, wood cost may increase by 8 percent [Nelson *et al.* 1993] to 25 percent [Thibodeau 1994]. The impact on silvicultural costs is estimated to be to negligible [Thibodeau 1994].

Under the variable retention silvicultural system, groups of residual trees will be left in the managed forest, which will reduce harvest volumes. The forecast reduction in harvest volume was estimated to be between 1 percent and 41 percent [Nelson 1993a; 1993b; Nelson and Shannon 1994; Thibodeau 1994], but reductions of between 32 percent and 54 percent were recorded in three other areas [Daigle 1992, as quoted in SPSFP 1995].

In 1995, British Columbia introduced a Forest Practices Code which is a comprehensive effort to ensure that publicly owned forests throughout the province are managed on a sustainable basis. The Code is complex, including legislation, manuals, and guidelines covering a variety of topic areas such as biodiversity, silviculture, and watershed management. The Forest Engineering Research Institute of Canada estimated that costs would rise by 20-30 percent to meet the Code [Nussbaum *et al.* 1996]. These estimates proved to be accurate.

In December 1996, forest industry representatives met with senior BC government staff to present their case that the industry was over-regulated and facing continued severe financial losses, even though softwood lumber prices were at record highs. A comprehensive assessment of changes in costs between 1992 and 1996 found that average delivered log prices rose from $Can 49.57/$m^3$ to $Can 86.74/$m^3$ throughout the province [KPMG 1997]. Of the $Can 37.17/$m^3$ increase, $Can 16.55 was due to higher royalty rates, $Can 12.22/$m^3$ was due to requirements of meeting the Code, and $ 8.40/m^3 was attributed to rising wages and input costs, increased harvesting of remote and rugged areas, and other non-Code-related regulatory changes. In response, the BC government recently announced measures to streamline the application of the Code.

A comprehensive assessment of changes in costs between 1992 and 1996 found that average delivered log prices rose from US$ 41.14/m^3 to US$ 63.32/m^3 throughout the province [KPMG 1997]. Of the US$ 22.18/m^3 increase, US$ 9.88 was due to higher royalty rates, US$ 7.29/m^3 was due to requirements of meeting the Code, and $ 5.01/m^3 was attributed to rising wages. Due to fall in the value of the Canadian dollar during this period, the increase as measured in local currency was roughly 15 percent greater than that shown in US dollar terms.

Summary of Wood Supply Impacts

Efforts to initiate an SFM system on the North American West Coast can be expected to:

- increase planning costs by 80 percent;
- raise road costs by 70 percent;
- increase yarding costs by as much as 20 percent or more in some areas, and
- force total wood cost increases of 8 percent to 25 percent.

The harvest volume is expected to decline by 1-54 percent, with the likely average regional decrease being close to 30-40 percent.

3. FOREST CERTIFICATION

In a few short years, forest certification has become one of the hottest issues in forest management. It is rapidly becoming a reality, with many of the world's largest forest-products companies either actively pursuing certification or seriously considering it. A number of organizations throughout the world have developed certification protocols for forest areas and/or products.

Under most systems, a "certified" product is one derived from a sustainably managed forest. Naturally, one of the main areas of debate is over what can be considered "sustainable". A related issue is who has the authority to set criteria and indicators for sustainability and who will be allowed to certify a forest as being sustainably managed. Major exporters such as Canada, Indonesia, and the Nordic countries are establishing specific forest management standards for their own forests as a basis for certification. FAO has proposed a Model Code of Forest Harvesting Practice [Dykstra and Heinrich 1996] and is testing its implementation in several case studies. Consuming nations are devoting their attention to establishing certification requirements for imported timber [Lyke 1996]. These issues are far from being resolved.

However, despite these uncertainties, companies, governments and other land owners are beginning to certify their forests. Lyke [1996] reported that seven independent programmes have certified at least 21 forests in Brazil, Costa Rica, Great Britain, Honduras, Indonesia, Malaysia, Mexico, Papua New Guinea, and USA. These forests have a total area of 4 million ha. As this trend continues, forest management practices on both certified and uncertified forests will shift as managers adopt SFM principles, with resulting impacts on intensity of harvest, area available for harvest, and silvicultural practices. The issue for our study has been to try to estimate these impacts. Ideally, the general approach would be as follows:

- identify which certification system(s) will be applied in a given country;
- estimate the area and proportion of current timber harvest that will be affected;
- examine the certification protocols and determine what impacts will occur;
- estimate how rapidly certification may proceed; and
- produce a schedule of impacts on the base-case scenario.

However, this approach cannot be implemented because of a lack of data, primarily because there are few reliable estimates of the full cost of certification (including the cost of upgrading practices as well as that of going through a certification assessment) and it is far from clear how many forests will actually become certified.

The actual costs of the certification process range from US$ 3500 to US$ 45 000 depending on the size of the forest and the organization of forest management [Nussbaum *et al.* 1996]. Nussbaum *et al.* [1996] also cited a cost of US$ 0.40/ha of undergoing the initial certification process. Subsequent annual audits are expected to cost between US$ 1000 and US$ 3000. The costs per hectare generally decrease with increasing forest size, making it somewhat easier for large-forest owners to be able to afford the cost. Ghazali and Simula (1996) cited an estimated direct cost of certification of US$ 1.30/ha for a 5000-ha forest, compared with a cost of US$ 0.08/ha for a 600 000-ha forest and a US$ 0.01/ha cost for a forest several million hectares in size. (Direct costs are the costs of undergoing the assessment, and exclude costs of upgrading forest management and putting a chain of custody tracking system in place.) However, for most producers, the largest costs associated with certification will surely be those required to upgrade forest management so that it meets the requirements of the certifying agency. Further costs are required to maintain forest management at this level. These costs are likely to be substantially greater than the costs of the actual certification process.

A theoretical analysis by Sedjo *et al.* [1996] began with the observation that most assessments of a certification process recognize that certification will increase the costs of industrial wood production and distribution. This is because certifiers are likely to require additional management practices that will almost surely increase the costs of harvests, if not timber growing. If a producer must incur a large additional cost to achieve certification standards, the producer is likely to avoid becoming certified or else will discontinue production. Sedjo *et al.* [1996] concluded that a fully certified system would likely result in higher market prices and lower wood output levels than without certification. In general, the reduced production would tend to result from reduced output by producers with higher certification costs. However, if certification of wood causes a significant substitution of demand from non-wood materials toward certified wood products, it is possible that the output levels could increase.

A major uncertainty is whether a price premium for certified wood will develop. If this happens, it will mark a segregation of the wood-products market into a certified segment and a non-certified segment. Furthermore, Sedjo *et al.* [1996] argued that if the cost of certification is less than the price premium, most producers will become certified. Those companies or owners who find that the costs of certification are greater than the price premium will either continue to produce non-certified wood or else drop out of the market altogether, reducing the overall supply of timber and putting upward pressure on prices.

However, there is little agreement on whether a market segregation will happen. Ghazali and Simula [1996] concluded that there is no convincing evidence that a price premium will be generally accepted for key forest products. They noted that the current global supply of certified timber, potentially as much as 3.5 million m^3/yr, is insignificant compared to the annual world output of industrial roundwood and equivalent, which is approximately 1.7 billion m^3/yr.

However, niche markets for certified wood have developed, especially in Europe and North America, supported by both the public and many retailers [Lyke 1996]. In addition, consumer surveys show a willingness to pay for certified wood products. A survey of furniture manufacturers found that 60 percent would prefer to buy certified wood and 28 percent said they would be willing to pay some premium for certified wood [Nussbaum *et al.* 1996]. Winterhalter and Cassens [1993] conducted a marketing survey asking people whether they were willing to pay for a wood product that was verifiably made of wood from a sustainably managed forest. Of the total respondents, 68 percent agreed that they would be willing to pay more for such a product. When asked to define the range of premium that they would be willing to pay, many were willing to pay substantially more (Table 3.1).

Table 3.1: Summary of consumers' willingness to pay a premium for products made from certified wood

Size of premium (% product price)	Proportion of affirmative respondents (%)
1 – 5	17
6 – 10	45
11 – 15	21
16 – 20	10
> 20	5

(Source: Winterhalter and Cassens 1993)

Ghazali and Simula [1996] reported that Swiss foresters are generally supportive of certification linked to SFM and forest owners were willing to pay at least CHF 0.40/m^3 for Forest Stewardship Council (FSC) certification. They also reported that the European Community Team of Specialists on Certification of Forest Products proposed two tentative scenarios for the market shares of certified products. Under the low scenario, between 10 and 20 percent of the market is certified wood by 2000 and 2010. The high scenario proposes that 40-50 percent of the market supply is certified in 2000 and, by 2010, this has reached 60-80 percent of the total market. Such scenarios are based on radically different assumptions regarding demand and the objectives and implementation strategies for certification. The ITTO Secretariat also conducted a preliminary assessment of the market impact of certification and used a scenario which saw certified timber account for 20 percent of the European market and 10 percent of North American markets [Ghazali and Simula 1996].

These studies indicate that it is reasonable to suppose that in the next 5-10 years, a higher proportion of the European wood-products markets will be certified than in any other region. North American markets are likely to have the second highest proportion of certified products in the overall wood-products market.

The impacts of certification on developing countries depend heavily on where their export markets are located. Salim *et al.* [1997] argued that the impact of certification on Indonesia's trading position will be minimal for the following three reasons:

1. Certified timber has only been a factor to date in niche markets where products have highly specific characteristics. There are few indications of any substantial consumer pressure to certify commodity products such as plywood. Seventy percent of Indonesia's forest-product export is plywood.
2. The demand for certified timber appears to be strongest in eco-sensitive countries such as Germany and Netherlands, and perhaps Belgium and Austria. A lesser degree of demand exists in UK and USA. Demand is virtually non-existent in Japan and Korea. Since Indonesian forest products are mainly exported to Japan, Korea and other East Asian countries, only a small percentage of its trade will be affected by consumer behaviour in the above-mentioned eco-sensitive countries.

3. Various studies on willingness to pay premium prices for certified timber products are discouraging. Salim *et al*. [1997] cited Ghazali and Simula's [1994] conclusions that even small product price increases resulting from timber certification could induce large changes in trade patterns.

However, Salim *et al*. [1997] reported that the main reason for Indonesia's decision to develop a set of certification standards is the national government's commitment to sustainable development and the global responsibility of Indonesia to safeguard its biologically complex and ecologically significant forests. This suggests that an economic analysis may provide only partial clues to the manner in which certified-wood-product markets might develop.

4. CONCLUSIONS

This study has examined evidence on the wood-supply implications of SFM adoption, biodiversity conservation, and certification. The concept of SFM has been broadened in recent years and the objectives of management are shifting in emphasis away from predominantly timber production towards ecological and social sustainability. Conceptualization of SFM has outpaced the development of specific on-the-ground practices that will achieve sustainability, and there are many knowledge gaps to be filled. Yet there are active efforts throughout the world to develop and implement SFM approaches, many of which take an adaptive management approach [e.g. CSA 1996]. What is striking is the substantial and increasing convergence in conceptual developments of SFM, even though the specific measures will differ by region, forest type, and socio-economic conditions.

Biodiversity conservation is widely seen as an integral component of SFM and it provides an excellent example of the need to gain knowledge and develop means of assessing complicated forest values. Certification protocols are being developed by many of the forest-product exporting countries and regions of the world. In many cases, these are linked to SFM but not everyone agrees on the required strength of the linkage. There is also widespread debate over many of the specific mechanisms that will be used to implement certification.

Some initial efforts have been made to estimate the impacts of adopting SFM. However, many of these are based on simulation models and trial operations - few could be considered representative of contemporary operations. We were unable to find reports of relevant studies from some parts of the world, notably Africa and Papua New Guinea. Nonetheless, there is a high level of consistency in the direction of the impacts, if not in their magnitudes.

In many cases, impact magnitude is based on a single study, so great caution should be exercised in accepting the magnitude of the impacts as being representative. However, the studies reviewed here consistently showed that there will be reductions in harvest volume, particularly in the short term, and costs can be expected to rise by between 5 percent and 25 percent, on average (Table 4.1). However, there is an expectation that long-term supply will increase through application of SFM. In the tropics, much of this increase is driven by the maintenance of site productivity and the retention and prevention of damage to immature stems. In temperate forests, the longer-term increase is less pronounced and may not be captured without intensified silviculture. Instead, the value of the harvest may rise as more large and high-value products are harvested.

Few studies report impacts on costs. Of those that do, costs are generally expected to rise. The exception is in the use of CELOS process (see Table 4.1). It was not possible to separate the costs of implementing biodiversity conservation from the costs of applying SFM. This is because many measures that support biodiversity conservation have only recently been implemented and these have been adopted in conjunction with measures undertaken for other purposes. The costs of implementing each measure were not usually separated in each study.

There will be some additional costs of implementing certification. These are primarily associated with undertaking measures required to meet the certification standards, rather than the costs of the actual assessment. Because it is unclear how many companies will opt for certification, it is difficult to say whether there will be a significant impact on overall wood supply costs or volume.

Perhaps the most significant result of this study is that a number of driving forces will lead to significantly improved forest management practices. Throughout the world, there is pressure to improve forest management. Even if only a small number of forest-products companies and forests become certified, it can be expected that the rest of the industry will continue to improve practices because the act of preparing certification criteria has raised the level of expected performance.

This general improvement entails a rebalancing of forest values and may lead to reduced timber-harvest volumes. Perhaps the relative value of non-timber forest values is rising faster than the value of timber, resulting in a reallocation of forest areas among competing uses, with the outcome of reduced timber harvests. However, in the longer term, there will be gains in some regions of the world as better management practices lead to the maintenance of timber productivity.

It is premature to attempt to assess the impacts of practices dedicated to biodiversity conservation because few companies or agencies can assess the present level of biodiversity in a forest area, let alone make a convincing case that they are conserving biodiversity. However, if biodiversity is indeed a key component of SFM, then measures to conserve biodiversity are likely to lead to short-term reductions in harvest volume but longer-term increases.

Table 4.1: Summary of cost and volume impacts of implementing SFM, by region

Region	Country	Case study	Volume reductions	Cost impacts
North America	West Coast	Clayoquot Sound	30-40%	8-25% cost increase
North America	Canada	White River	10-25%	Increase
North America	Canada	Seine River	24%	
Europe	Sweden	A. Berklund	6-8%	NA
Asia	Malaysia	Sarawak	50%	Increase
Asia	Malaysia	Innoprise Corporation	6-8%	5% cost increase
Asia	Malaysia	Dermakot	up to 100%	
Asia	Indonesia	Indonesian Plan	18.4%	
Asia	Indonesia	STREK Project	9 - 15%	Increase
Latin America	Bolivia	Chimanes	24 - 57%	35-67% loss in profits to logging contractors
Latin America	Eastern Amazonia, Brazil	Paragominas Region	up to 100%	$ 72/ha increase
Latin America	Brazil	Precious Woods	24-57%	0% cost increase but assumes more trees as commercial species
Latin America	Suriname	CELOS	9%	10-20% cost savings
Latin America	Costa Rica			Increase

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