TOWARDS A SUSTAINABLE

Paper Cycle

Sub-Study Series

3 Northern Temperate and Boreal Forests

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International Institute for Environment and Development

NORTHERN TEMPERATE AND BOREAL FORESTS

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Executive Summary

The production of paper is a key economic activity representing one per cent of the world's total economic output. Global consumption doubled between 1975 and 1991 and is expected to increase an additional 80 per cent by 2010. Given this future outlook, it is important to assess whether paper production is sustainable at present and future levels of consumption.

In an attempt to address this issue, a project was initiated to examine the sustainablility of the paper cycle. In order to obtained a balanced, impartial view of these issues, the World Business Council for Sustainable Development commissioned the International Institute for Environment and Development to carry out a study of all phases in paper production which included this independent sub-study of the sustainability of forest management in the boreal and temperate forests.

Traditional forest management methods emphasised wood production with an objective of sustainability that was limited to timber production. The forests resulting from this management approach were unattractive to the general public and produced little in the way of other benefits or values. In this report we have called this approach 'sustained yield timber management'. The scope of forest management has now broadened considerably. Many forest managers are now beginning to think in terms of managing ecosystems, generating a wider range of products, and taking into account the social impacts of their actions. This is particularly so on publicly owned land. There is a variety of terms used to describe these new approaches and the concepts are still evolving. However, underlying these various approaches is an emphasis on managing and sustaining ecosystems: hence we have called these approaches "ecosystem management". The primary focus of this report is to assess the impact of the impending environmental, social and economic impacts on fibre production of the shift from sustained yield timber management to ecosystem management in the world's northern boreal and temperate forests.

A primary theme found in current literature on forest management is the recognition that management impacts occur on a range of temporal and spatial scales. Temporal issues were largely side-stepped by artificially designating two periods for comparison: the present and the future. The present period is the frame of reference used for our discussion of the sustainability of traditional practices (i.e. sustained yield timber management). In reality, management approaches are shifting gradually and unevenly towards ecosystem management. There is enough momentum to suggest that ecosystem management will become widely applied in all regions. However, there will be a lengthy transition period as ecosystem management is implemented. Rather than

try to predict the length of the transition period, we have conducted our assessment of ecosystem management impacts at some future point in time when it is widely applied and its impacts fully realised.

The differing impacts at different spatial scales was addressed here by dividing the northern hemisphere's boreal and temperate forests into regions and then observing individual case study areas for more detailed results. The regions include:

- ◊ North American Boreal
- ◊ Eastern North America Temperate
- ◊ Western North America Temperate
- ◊ Southern US Temperate
- ◊ former USSR Boreal
- ◊ European Boreal and Temperate
- ◊ Nordic Boreal

Regions were identified largely based on forest type, which in turn influences forest management techniques and issues. The regional discussions describe the characteristics of the main forest types, the overall level of harvesting, and the practices that define the application of sustained yield timber management and ecosystem management. Within each region, and where possible, representative case study forest areas were identified for more detail and quantified information. The studies were, in effect, indicators of the possible impacts of adopting ecosystem management.

Once the regional analysis was completed we undertook to review criteria and indicator reports and select a set of environmental, social and economic indicators most appropriate for this project. From these, we determined a set of indicators to assess the impacts of the shift from sustained yield timber management to ecosystem management for the boreal and temperate regions.

There has been a vast amount of literature published on what we have called the traditional approach to forest management. Quantitative and qualitative data are readily available on almost all management activities in all forest types. In contrast, ecosystem management has generated some qualitative estimates but relatively little quantitative results. This situation prevented us from delivering quantitative assessments of many indicators and it was beyond the terms of the project collect or develop new data. Case study results have been cited as proxies for ecosystem management impacts with the recognition that these are preliminary estimates.

The main conclusions are:

- The traditional focus of professional foresters on the sustainability of the timber supply is no longer appropriate for sustaining forests. In order to take a new approach we need new tools and a broadening of principles for forest management

- Ecosystem management is becoming more widespread, albeit it is occurring at different rates in different regions and also at different times.
- Ecosystem management will restructure timber economies, particularly in terms of timber harvest costs, volume harvested and wood quality. A critical aspect of this restructuring is the rate of change that government, private landholders and companies can accept and still remain viable.
- A shift towards ecosystem management will improve the ecological and social sustainabilty of forest operations which will come at the expense of narrowly defined economic indicator values.
- Land use planning and ecosystem management are closely intertwined. The philosophical debate over the best means to implement ecosystem management is still in the infancy stage.
- Land ownership has a profound impact on the type of forest management practise.

In light of the findings in this study, we recommend the following:

- Conduct more in-depth case studies to determine better quantitative measurements at the operational level.
- Include the remaining boreal/temperate forests regions in the analysis.
- Re-examine timber supply assumptions particularly in terms of defining the economic wood supply, the quality of wood and the sustainability of forest harvests from forest plantations.
- Determine the social and economic restructuring implications of adopting ecosystem management practises.

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1.0 Introduction

1.1 Sustainable Paper Cycle Project

The production of paper is a key economic activity representing one per cent of the world's total economic output. Global consumption doubled between 1975 and 1991 and is expected to increase an additional 80 per cent by 2010 (FAO 1993 and FAO 1994). Given this outlook, it is important to assess whether paper production is sustainable at present and future levels of consumption. If not, it suggests that demand will outstrip supply, resulting in rising prices, and there will be intense pressure on the world's forests. The answer to this problem contains important information for governments and private investors who may be considering investments in plantations or other forest management measures. The impacts will also affect all land use policy, especially that with regard to forest land.

In an attempt to address the problem, a project was initiated to examine the sustainablility of the paper cycle. In order to obtained a balanced, impartial view of these issues, the World Business Council for Sustainable Development commissioned the International Institute for Environment and Development (IIED) to carry out a study with the following objective:

> In the context of sustainable development, assess the role of paper and the paper industry world-wide focusing on the entire cycle from fibre production (including forestry) to pulp and paper production, paper usage, recycling, energy recovery and final disposal.

The first stage in the paper production cycle, forest management and fibre harvesting operations, provides the primary raw material input. In order to assess the sustainability of fibre production in the northern hemisphere, IIED commissioned an independent sub-study of forest management in the boreal and temperate forests.

1.2 Study Objectives and Methodology

The practice of forest management is changing rapidly throughout the northern boreal and temperate forests. Changes are being driven by factors such as public disapproval of traditional methods, rising timber prices and impending wood fibre scarcity in some regions, and improvements in technology. As a result, there is no single widespread approach to forest management, even within a particular forest region. Traditional forest management methods emphasised wood production with an objective of sustainability that was limited to timber production. The forests resulting from this management approach were unattractive to the general public and produced little in the way of other benefits or values. In this report we have called this approach "sustained yield timber management".

Within that last ten years, the scope of forest management has broadened considerably. Many forest managers are now beginning to think in terms of managing ecosystems, generating a wider range of products, and taking into account the social impacts of their actions. This is particularly so on publicly owned land. There is a variety of terms used to describe these new approaches and the concepts are still evolving. However, underlying these various approaches is an emphasis on managing and sustaining ecosystems: hence we have called these approaches "ecosystem management".

Instead of preparing separate assessments of generic applications of both sustained yield timber management and ecosystem management, we have decided to examine the changes in sustainability as managers move towards ecosystem management, since it is clear to us that this is the broad trend in forest management and few companies will be willing or able to resist it.

Therefore, the primary objective of this study is:

> ***To assess the environmental, social and economic impacts on fibre production of the shift from sustained yield timber management to ecosystem management in the world's northern boreal and temperate forests.***

A primary theme found in current literature on forest management is the recognition that management impacts occur on a range of spatial and temporal scales. The differing impacts at different spatial scales was addressed here by dividing the northern hemisphere's boreal and temperate forests into regions and then observing individual case study areas for more detailed results.

Regions were identified largely based on forest type, which in turn influences forest management techniques and issues. The regional discussions describe the characteristics of the main forest types, the overall level of harvesting, and the practices that define the application of sustained yield timber management and ecosystem management.

However, regional statistics are too coarse to describe many of the impacts of moving from sustained yield management to ecosystem management. For this purpose, the most appropriate spatial scale is the "forest unit" level. In most of North America and Russia, a forest unit is likely to be a rather large, contiguous area that is managed as a single administrative unit and may range from 250,000 to 750,000 hectares or larger. The boundaries of the forest unit are usually determined by factors such as mill location, watershed boundaries, ecological zones, and other administrative or political boundaries. In Europe and Scandinavia, a forest unit is more likely to be a scattered collection of small forest areas with a variety of owners. In both cases however, a forest manager is responsible for meeting a set of objectives expressed on the basis of the entire forest unit. Typical management objectives include the volume of timber harvested, quantity of wildlife habitat provided, and amount of employment generated. Since forest units are managed as discrete supply areas, this is where the impacts of changes in management will become most evident. Examining impacts at a smaller scale is unsuitable because the sustainability impacts of the activities undertaken in one forest stand or harvest block can only be judged in the context of the other activities taking place in the unit.

Temporal issues were largely side-stepped by artificially designating two periods for comparison: the present and the future. The present period is the frame of reference used for our discussion of the sustainability of traditional practices (i.e. sustained yield timber management).

In reality, management approaches are shifting gradually and unevenly towards ecosystem management. There is enough momentum to suggest that ecosystem management will become widely applied in all regions. However, there will be a lengthy transition period as ecosystem management is implemented. Rather than try to predict the length of the transition period, we have conducted our assessment of ecosystem management impacts at some future point in time when it is widely applied and its impacts fully realised.

Within this spatial and temporal context, we undertook the following steps:

1. Divide the world's northern hemisphere temperate and boreal forests into regions suitable for analysis.

Throughout the world, approaches to forest management are designed with reference to the attributes of the component tree species. Since meeting the project goal requires an examination of management practices in the major commercial forest types, this was best accomplished on a regional basis. In this work step, the consultants identified a series of forest zones throughout the forests of the northern hemisphere. In making these divisions, project requirements were balanced against data availability constraints.

2. Review criteria and indicator reports and select a set of indicators most appropriate for this project.

Numerous lists of criteria and indicators have been developed in recent years as tools to assess the sustainability of forest management practices. From these, we determined a set of indicators appropriate to the goals of this project. The criteria used to select indicators were the usefulness of the indicator and availability of data to assess each indicator.

3. Identify and review the major management systems applied in each region.

Two broad classes of management system were distinguished: sustained yield timber management and ecosystem management. Various techniques of undertaking management were discussed in the context of both management systems. Since it is anticipated that the reader understands the concept of sustained yield, this report spends considerably more time explaining the regional variations of ecosystem management that we found reported in the literature.

4. Identify areas that are relatively representative of the region's forests and where recent, detailed and quantifiable information is available regarding impacts of adopting ecosystem management. The studies conducted in these areas were treated as case studies of the impacts of adopting ecosystem management.

A variety of impacts can only be assessed at the forest unit level. Case studies were used as the basis for presenting this type of information. For most regions, there were only one or two studies available which reported quantitative estimates of some of the impacts of adopting ecosystem management. In most of these cases, some cost and volume impacts were estimated but few other impacts have been measured.

5. Identify and review published evidence to assess the impacts of current practice and the expected impacts once more comprehensive frameworks for ecosystem management are designed and implemented.

Since ecosystem management is only beginning to be practised in an integrated manner, case studies and test implementation areas were the primary data sources within each forest region.

6. Assess the impacts of the shift from sustained yield timber management to ecosystem management using the selected indicators.

In this step we assess the environmental, social and economic impacts of the shift to ecosystem management. While the assessment for each indicator is frequently qualitative, this approach is useful in identifying broad directions of change and highlighting regional differences.

The indicators used here are meant to be examined as a set; one indicator by itself may not provide an unambiguous measure of sustainability. Why is this? The main reason is that sustainability is a complex attribute, especially when viewed in an economic, environmental, and social context. Furthermore, a broad definition of sustainability embodies the notion of trade-offs. This is clear from the idea of sustainable development, which holds that economic sustainability can only be achieved if the environment is managed sustainably (and vice versa). Thus, development must proceed at a balanced, measured rate over the long-run. In the short run, most people would argue that the major task is preventing heedless economic development. Measures that result in the environmental indicators showing more sustainable readings are likely to result in the deterioration of at least some economic indicator levels.

1.3 Project Scope

As with any project that undertakes a global level of assessment, the authors were forced to limit the scope of inquiry to preserve the manageability of the project. This has been done by avoiding the presentation of tedious technical detail when describing how various operations will be undertaken. The authors have also tried to minimise the amount of unnecessary repetition; where the same general kinds of impacts could be expected in a number of forest zones there was no need for a zone-by-zone recounting of the impacts.

There has been a vast amount of literature published on what we have called the traditional approach to forest management. Quantitative and qualitative data are readily available on almost all management activities in all forest types. In contrast, ecosystem management has generated some qualitative estimates but relatively little quantitative results. This situation prevented us from delivering quantitative assessments of the indicators and it was beyond the terms of the project collect or develop new data. Case study results have been cited as proxies for ecosystem management impacts with the recognition that these are preliminary estimates. One obvious area for future effort is in compiling and developing of quantitative measures for each indicator in each of the different regions.

One problem with adopting a qualitative approach is that it becomes difficult to predict the net effects of a number of opposing impacts. For example, the area of forest land available for commercial timber harvesting may increase if people feel that ecosystem management enables timber harvesting to be compatible with the production of many other values. On the other hand, it may be determined that more land should be exempt from timber production in order to protect poorly represented ecosystem types (such as mature softwood forest). The net outcome is not easy to deduce and may well vary from region to region. In situations such as this, where the strengths of the opposing impacts might be roughly equal, we describe the components of the overall equation but do not attempt to definitively state the net result.

In the next section, we present an overview of the principles underlying the two major forest management approaches, followed by a description of the methods or techniques of undertaking common forest management activities. Section 3.0 presents a description of the forest types found in each region. We also provide some historical context for present conditions in each forest zone and describe these verbally and with the aid of some common forest management statistics. Finally, the regional descriptions each conclude with a more specific discussion of how sustained yield timber management and ecosystem management are adapted to suit the characteristics of the region and its forests.

In section 4.0, we describe each indicator used in this assessment and then describe how each indicator can be expected to change as ecosystem management is implemented. These discussions combine general results with specific regional illustrations. We summarise our conclusions in section 5.0 and present a list of references in section 6.0.

2.0 Overview of Forest Management Principles (Systems) and Techniques

2.1 Introduction

The forest management literature contains a plethora of confusing and overlapping terms that describe different systems and approaches to forest management. This report concentrates on the distinction between activities that are undertaken on specific stands or harvest blocks and broad sets of principles that form a framework for managing large forest ecosystems or landscapes.

Harvesting, planting, seeding, and thinning are examples of typical forest management activities. Each of these activities can be carried out using one of a number of techniques. For example, seeding can be done aerially or it can be applied in various ways by people working on the ground. There are many techniques available for harvesting timber, for preparing a harvested site for the next forest, and for planting and other reforestation activities. Collectively, the undertaking of these activities constitutes forest management.

However, the main objective of this project is to assess different approaches to forest management and its implication for future wood supplies. This goal cannot be accomplished by simply examining the techniques, since the scale at which they are applied is inappropriate and since a great number of these techniques are used on any given forest or landscape at any one time, which complicates attempts to present a general discussion. Instead, the underlying sets of management principles must form the basis of an assessment of sustainability, and it is by comparing the implications of managing according to different sets of management principles that the objectives of this project will achieved. Principles and techniques are related in the following manner: the set of forest principles governs the manner in which the various techniques are deployed within a forest.

The authors have chosen to distinguish two sets of forest management principles. The current standard set of management principles is referred to as sustained yield timber management. This describes how most forest managers have operated during the past two or three decades, both on public and private land. By and large, it also describes the current approaches to management. This set of principles is elaborated in the next section.

The alternate set of forest management principles that we wish to examine can be described as forest ecosystem management. Ecosystem management encompasses most of the precepts known as New Forestry. New Forestry was described to the broad forestry profession for the first time by Jerry Franklin in his 1989 article "Towards a New Forestry". The term "ecosystem management" originated at roughly the same time, but it appears to have been developed in response to work done by landscape ecologists, ecosystem diversity experts, and wildlife managers. In fact, Grumbine (1994) refers to the pioneering studies of the grizzly bear in and around Yellowstone National Park as providing a concrete example of how then-current management practices were inappropriate and would not work over the long term.

New Forestry and ecosystem management share many of the same values and objectives and any differences between the two approaches are minor. Therefore, in this report, New Forestry will be included as ecosystem management. The set of ecosystem management principles is in the process of being more fully understood. In some forest areas, ecosystem management is in the initial stages of implementation while it has not yet been tested in other areas. This emerging set of principles is described in section 2.3.

For the purpose of comparison, this assessment treats the two sets of management principles as being distinct. However, the shift from one set of management principles to another is not marked by a sharp break. Instead, the process is a gradual transition. The rate of change depends on how quickly the implications of the new principles can be understood and translated into practices, and also on how quickly the new ideas are accepted. Current practice has a number of elements that can be considered to reflect ecosystem management principles, however, it will take some years before a global ecosystem management approach is enunciated and implemented.

The remainder of section 2 is devoted to an overview of the various techniques that are available. Section 2.4 describes harvesting techniques, section 2.5 examines techniques of regenerating forests and section 2.6 covers some of the other techniques of management that are applied for purposes ranging from hazard control to density management. The final part of this section explains the relationship between management intensity and the various suites of activities that are undertaken on a forest site.

2.2 Sustained Yield Timber Management

Virtually every forest manager subscribes to the principle of sustained yield. At its most basic level, sustained yield forestry dictates that the volume of timber harvested from a forest does not exceed the volume of timber growth in the forest. When sustained yield management is practised, the forest will provide a continuous supply of timber and will not be depleted over time. There are some variations in the way sustained yield management is applied. Some forest managers allow harvesting to temporarily exceed the volume of growth in older forests which have relatively high volumes of standing timber and relatively low growth. However, as these older forests are harvested, the harvest volume can be expected to decline until it equals the volume of growth expected over the long run. Thus, sustained yield management does not necessarily imply that the harvest level must be uniform over time.

If the manager decides to undertake widespread planting and intensive cultivation, this will increase the overall forest growth rate and enable the forest to provide a larger timber volume. It is important to understand that the volume of timber growth is a variable that can be affected substantially by the techniques that the manager chooses to employ.

The approach to sustained yield forestry that is practised throughout much of North America, if carried out over a long period of time, will in theory lead to the creation of a so-called "normal" or "regulated" forest. In a normal forest, there is a roughly equal area of forest in each age class and the oldest class present in the forest is just reaching the age of harvest. Such a forest provides an equal harvest volume each year in perpetuity and requires undertaking a uniform level of the required forest management activities every year. A normal forest is often extolled because it is sustainable, provides an even flow of timber, and is easy to administer. However, most managers never expect to attain a normal forest because economic, social, and technological conditions are likely to change to such an extent that the "target" normal forest will continuously evolve over time. In addition, losses to fire, pests, and windstorms disrupt the progress towards a normal forest, as do fluctuations in harvest level as industrial conditions change. However, the creation of a normal forest is the eventual outcome of sustained yield forestry espoused by most managers.

This approach to forest management embodies a focus on timber that has led managers to largely ignore other forest values. Many foresters operated under the assumption that the best use of the forest is for timber production, and whatever other benefits are produced is of secondary importance. Others simply assumed that a forest operated as a commercial timber production centre produced a socially desirable set of values. From a production-oriented perspective, these assumptions were true. Other forest values are difficult to value and have usually been assumed to be worth less than the value of timber. Foresters also felt that a vigorous forest would be a healthy forest, since healthy trees are more resistant to disease and damage. Finally, the road access provided by forestry activities benefited local recreationists and also aided forest management. However, the arguments in support of these assumptions have proven to be inaccurate or have at least ignored other important factors. As a result, legislators have enacted various regulations restricting areas of operation, clearcut sizes, and other aspects of the timber producing operation; however, the focus still remained on timber production.

Seeing the forest as a factory for producing timber also led managers to attempt to minimise the financial cost of obtaining timber. For this reason, large clearcuts were favoured; harvesting costs were low and planning and set-up time was minimised. The prevalence of this harvest approach is remarkable; in 1991, 85.9% of timber harvesting in Canada was performed using clearfelling (CCFM, 1993). Clearcutting may be followed by natural regeneration, seeding, or planting. Often some form of site preparation is performed. Since coniferous stands tend to be more valuable than hardwood stands, herbicides were frequently used to control hardwoods and other unwanted competition. The use of herbicide is coming under pressure from the public and from environmental groups. However, if herbicides are not allowed, managers have few other economically viable means of controlling competition. Manual methods of release and even the use of sheep have been tried but are not feasible on any significant scale due to both costs and assorted logistical problems.

Although large areas of cutover were left to regenerate naturally or seeded, plantations were established where the financial returns were favourable.

Plantations are highly structured forests that are artificially established using seedlings or cuttings of either natural or genetically superior stock. The component stands are even-aged, although they may be removed during a series of harvests rather a single clear-cut. The establishment of a plantation is often preceded by site preparation activities including plowing, disking, and scarification. In many plantations, trees of a single species are planted in rows.

Multi-species plantations are viable provided that the species are compatible. The use of plantations provides a manager with a high degree of control over species composition and stocking and the promise of uniform sized trees grown more rapidly than in natural stands. The control of stand density and the provision of optimal conditions for stand establishment generally accelerates the rate of stand development.

Plantations are most attractive in the US South and Pacific Northwest, where growth rates are high. The US South has the added advantages of relatively low labour and flat land which is amenable to agricultural production methods. During the past five decades, the establishment of industrial plantations has accelerated. Part of the reason for this is that most industrial private land owners do not see themselves as being obligated to provide a wide range of benefits to society and instead concentrate on the production of raw material. Private landowners also have more security of tenure than licence holders on public land, and hence have more incentive to invest more on their land. Finally, private land is on average more productive than public land, and higher intensities of management are financially justified. Thus, the forest management principles that are followed depend in part on who owns the land.

Various forms of uneven-aged management are practised in some areas, especially where tolerant hardwoods pre-dominate. Yet even here, the emphasis is on growing industrially valuable trees and attempting to maximise the financial return. Many private landowners simply high-grade their forests; removing the merchantable timber and leaving the rest behind. With the narrow focus on timber, it is not surprising that forestry operations have been targeted by environmental protesters. What is surprising is that it took so long for an alternate forest management paradigm to develop.

2.3 Ecosystem Management

We have made an extensive survey of recent literature that describes alternatives to traditional sustained-yield timber management. In the 1970s and 1980s, the language used to describe such alternatives included such terms as multiple use management, holistic resource management, and integrated forest management (see Bull, 1995, for a thorough review). 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).

For the purposes of this report, we have decided to gather ALL proposals for improved forest management and designate them as ecosystem management. We have done this because the concept of ecosystem management, while still evolving, is being defined to embrace improvements in just about every aspect of forest management. As far as we can tell from the forestry literature, almost every proposal for improvements on traditional (sustained yield) timber management calls for changes in either ecological or social performance, or both. Improved forest management in the 1990s, economic efficiency gains notwithstanding, means balancing commodity production with ecosystem conservation and social concerns. We illustrate with two recent papers describing ecosystem management.

Grumbine (1994) offered an historical view of the evolution of ecosystem management in North America. His extensive literature review revealed ten dominant themes in ecosystem management, as shown below (Table 2.1):

TABLE 2.1. DOMINANT THEMES IN ECOSYSTEM MANAGEMENT.

Theme	Description
1. Hierarchical Context	Managers must understand the connections between all levels of the biodiversity hierarchy (genes, species, populations, ecosystems, landscapes).
2. Ecological Boundaries	Management should be designed for appropriate ecological boundaries.
3. Ecological Integrity	The protection of diversity and the ecological patterns and processes that maintain that biodiversity.
4. Data Collection	EM requires much greater knowledge than is presently available; there is a need to gather new data.
5. Monitoring	The impacts of activities must be monitored and results incorporated in subsequent management.
6. Adaptive Management	Management can be viewed as a process of obtaining knowledge about the forest ecosystem; management should be organised to facilitate learning.
7. Interagency Co-operation	There is a need for co-operation between the various agencies that are responsible for different areas and ecosystem components.
8. Organisational Change	Organisations will have to modify how they do business.
9. Humans in Nature	People are part of nature. Humans influence ecological processes and are influenced by them.
10. Values	Human values play a dominant role in determining the goals under ecosystem management.

Gerlach and Bengston (1994) posed eleven challenges for ecosystem management, and in so doing also painted a broad picture of the basic determinants of ecosystem management:

1. Co-ordinate across established political borders, institutional cultures and other differences to manage on ecosystem scale.

2. Co-ordinate across time horizons different from and usually far longer than those around which decision making and management is conventionally grounded.

3. Co-ordinate holistically, across solutions.

4. Make decisions using assessment information which is ambiguous and uncertain.

5. Avert 'tragedy of the commons,' that is, assure that resource uses which are narrowly rational also combine systematically to serve the common good.

6. Make changes in rights and duties in natural resources, and thus in property relationships and broader social structure.

7. Reduce inequities (increase fairness) in the distribution of costs and benefits of natural resource use and environmental change.

8. Develop in ways which are ecological and sociopolitically sustainable.

9. Institutionalise ecological and economic interdependence democratically.

10. Resolve conflicts associated with accomplishing these tasks.

11. Integrate sociocultural (human) factors and biophysical factors in carrying out the ecosystem approach.

Given such themes and challenges associated with ecosystem management, one gets the impression that ecosystem management (or sustainable forest management, for that matter) represents just about all improvements that could conceivably be made in the total forest management system! For this report, we favour an inclusive interpretation of the ecosystem management concept. Our review of proposals for alternatives to sustained-yield timber management, which we incorporate under the name of the ecosystem-management, reveals that they must:

1. focus first (almost always) on improving ecological conditions in forests, especially those associated with biodiversity, ecosystem productivity, soil and water, and element cycles (e.g., carbon, nitrogen);

2. deal secondly (often) with improved social performance of forest management, including broadening the array of uses for which forests are explicitly managed, and making decision-making processes more inclusive and democratic; and

3. deal infrequently (if at all) with the subject of high timber production at low cost for industrial uses.

The details of the ecosystem-management proposals we have managed to find in the literature are given with the regional forest descriptions below.

In all regions, the adoption of ecosystem management can affect future fibre production levels in a number of ways. Chief among these are:

1. Lengthening the rotation age to maintain a more ecological age class distribution.
2. Less inputs into silviculture which will mean more stands are slower in getting included into yield projections.
3. Less volume removed in each cutting cycle in order to protect other forest values
4. Decrease utilisation of logs since coarse woody debris left on site is good for ecosystem management in many areas.
5. Change the definition of productive forest land.
6. Prescribe burning, as a management practise will introduce increase the risk of losses due to escaping fires.

2.4 Overview of Harvesting Techniques

This section is intended to provide an overview of the common forest management systems used in the northern boreal and temperate forest regions and describe some of the alternative systems that are being discussed and implemented. The discussion will be very general in nature since there are a great many variations of the basic form of each practice. In most forest types (especially those dominated by softwoods), clearcutting is the most common timber harvesting technique. This is described in the following section. Subsequent sections describe three alternate techniques for harvesting: modified clearcutting, shelterwood, and selection forestry.

2.4.1 Clearcutting

Forestry Canada (1995) defines clearcutting as "A forest management method that involves felling and removing a stand of trees. Clearcutting may be done in blocks, strips or patches." Although the name suggests that all trees on an area are removed , in practice, clearcutting can also be said to occur when all merchantable trees are removed and only unmerchantable trees are left behind.

For species that are intolerant of shade and normally develop as even-aged stands, clearcutting is often desirable since it favours the regeneration of the same species. Softwoods and poplars are the species groups most likely to be managed as even-aged stands and so are likely to be clearcut. Ecosystems characterised by catastrophic disturbances, particularly fire and wide-spread pest epidemics, often contain a high proportion of even-aged stands. Now that fire suppression is the norm throughout much of the forest (an exception is the extreme north, beyond most commercial activity), it is also argued that clearcutting is the nearest readily available replacement for fire. Thus, the Ontario Environmental Assessment Board was "persuaded that clearcutting is an acceptable timber management practice, particularly for the boreal forest" (EA Board, 1994).

Clearcutting is appealing to industry since almost all facets of it are cost effective, ranging from access to planning to the actual cost of the operations. However, there are also disadvantages associated with the method. Most of these problems centre around the complete removal of merchantable material from an area. There is no question that clearcutting disrupts the ecological processes within the areas that are cut. Clearcutting also leaves these areas exposed to the threat of soil erosion, especially where land is sloped and the soil is thin. Clearcutting can disrupt fish and wildlife habitat, especially when there are few residuals of buffers areas left behind. There are also concerns that whole tree harvesting, a practice in which the entire tree is taken to the roadside for removal of tops and branches, degrades the level of nutrients and organic matter on the site.

Furthermore, as with any harvesting technique, clearcutting can be done poorly and this often results in long-term site damage. Poor practices include clearcutting excessively large areas, clearcutting slopes or other sensitive sites, not leaving buffer zones along waterways and other sensitive areas, and harvesting in spring and at other times when the ground is wet. Poor layout and construction of roads and bridges also leaves areas vulnerable to washouts, erosion, and flooding. More than anything, it is the poor examples of clearcutting that have drawn the ire of the public. Most managers believe that alternate harvesting and silvicultural techniques are incompatible with the development habits of a number of species, especially conifers. As a result, the reaction of the forestry profession has been to argue the ecological appropriateness of properly executed clearcuts, and alter practices by reducing clearcut size, breaking up harvest areas by leaving patches of standing timber, leaving more extensive buffer areas, and improving the design of harvest blocks to mitigate the adverse visual aspects.

2.4.2 Modified Clearcutting

The chief difference between modified clearcutting and traditional clearcutting is in the design of the harvest layouts and the use of primarily natural regeneration under the modified approaches. One modified clearcutting technique is the seed tree method, in which scattered individual trees or small clumps of trees are left to provide seed for the next stand. This method works best when the residual trees are windfirm and produce abundant seed that is easily dispersed by wind. The seed trees may be harvested once the new stand is established or they may be left behind for ecological value.

Also considered in this group of systems is the two-pass harvest system and strip and block cutting. The two pass system is used when a stand has two substantial components which are at different levels of maturity. The idea is to first harvest the component that matures earliest, taking care to minimise damage in the residual stand. When the residual stand matures, it will be harvested. Usually, the stand components are distinguished by species as well as age. This system has been used in white spruce/aspen mixed woods of western Canada (Fronning 1980) and in balsam fir/spruce stands in the Maritimes.

Strip cutting involves sub-dividing the cut block into narrow (e.g. 40-100 m wide) strips and cutting these in two or three passes. If a two-pass system is used, the first harvest will remove alternate strips. The leave strips provide seed to regenerate the cutover strips and are removed once new growth is well established in the cutover strips. In a three pass strip cut, one third of the forest area is cut in each of three passes. Block cutting follows the same principles as strip cutting using a series of small block shaped cuts, rather than strips. Each block is rarely larger than several hectares in size.

2.4.3 Shelterwood

The second broad class of alternate silvicultural systems is shelterwood. The basic principle is to remove the existing canopy in stages so as to allow a new stand to regenerate beneath the existing one. The existing canopy provides seed and protection for the new stand and is removed once the second stand has firmly established itself, according to the traditional version of the prescription. New forestry advocates have suggested that the final cut not be made, leaving a remnant of the older forest intact to provide structural diversity and aesthetic value.

A shelterwood prescription may involve from two to four partial cuts, including the final removal of the remaining mature canopy. These cuts are usually made at 15-20 year intervals. The classic, four-cut shelterwood is often prescribed for white pine in Ontario (Chapeskie et al. 1989). The first of the four cuts is made when the stocking of the stand is relatively high. This pass, known as the preparation cut, is intended to make room for the crowns of the dominant trees to expand and increase their seed production capability. This cut removes undesirable species, smaller trees (i.e. suppressed, intermediate, and perhaps some co-dominant trees), and low quality stems. The second cut is the regeneration cut, which is undertaken in an early stage of the new stand's development. The purpose of the regeneration cut is to create conditions that favour the establishment of regeneration, which in this case means increasing the light level on the forest floor. The new stand is expected to establish itself in the period following the regeneration cut. The remaining canopy may then be removed in two stages. The first removal cut leaves enough older trees to reduce the incidence of white pine weevil, which deforms trees and lowers their economic value. The second or final removal cut is made after the new stand has passed through the stages where it is most susceptible to weevil.

Careful control of canopy density is required throughout the application of the system. For example, leaving too many trees after the regeneration cut will create too much shade for the regeneration to survive whereas too much cutting will allow less tolerant competition to develop. Severe competition from hardwoods and other undesirable vegetation can be expected on moist to fresh sites, which are frequently nutrient-rich. On such sites, Chapeskie et al. (1989) suggest that artificial regeneration and competition control will be required to successfully regenerate white pine.

The success of the shelterwood system rests on the ability of the forest manager to act if desired regeneration does not establish itself or becomes subject to severe competition. This in turn requires that the development of such sites be monitored regularly, especially after the regeneration cut. Regular monitoring also allows the manager to take advantage of the flexibility offered by the shelterwood system. Ultimately, the growth requirements of the regenerating stand should determine the most appropriate harvest intensities, the intervals between passes, and even the number of passes. It is also important to consider the economics of the harvesting operations, which depend on the volume and value of the trees to be removed and the potential for damaging the regeneration.

2.4.4 Selection

The selection system differs from all other systems in that felling and regeneration are not confined to specific areas within a stand or forest (Matthews 1989). Instead, individual trees or small groups of trees are selected for harvest on the basis of the impact on the residual stand and their contribution to the harvest. In its usual application, the selection system is applied so that the manager will, over time, create a forest with a specifically desired structure.

In temperate forests, forest structure is often defined by parameters that describe the distribution of stem sizes and by the upper diameter limit. Forest structure is often determined simultaneously with the desired species composition. In the boreal forest, species characteristics are such that a manager is more likely to maintain a structure consisting of three or more distinct age or size classes, rather than a continuous distribution of age or size classes.

The use of the selection system usually assumes a reliance on natural regeneration, although underplanting may be used to bolster the occurrence of a species. To move the forest towards the desired state, a manager is able to manipulate the intensity of harvest (often expressed in terms of basal area per hectare), the interval between harvests, as well as the priorities for selecting trees for harvest.

2.4.5 New harvesting techniques

There are many new harvesting techniques referred to in the literature and they are either a renaming of a technique described above or a combination of these traditional techniques. The emphasis is either on cutting trees for purposes other than timber production or on describing the forest which remains once cutting has occurred. The new harvesting techniques include: wildlife shelterwood systems, unit area control method, light or medium conifer retention, and the variable retention silvicultural system. The reader will notice the harvesting technique and regeneration technique with ecosystem management is now difficult to distinguish, since the primary focus of harvesting is now on the regeneration of the forest.

2.5 Overview of Regeneration Techniques

The traditional tree regeneration techniques are classified as either natural or artificial. Natural regeneration refers to the use of existing tree seed sources or advance regeneration to reforest the area naturally, i.e. there is no human intervention in the establishment of the forest crop.

Artificial regeneration requires human intervention in one of two ways: by planting young trees generally grown in nurseries or by distributing seed on the site. Both of these techniques frequently require prior application of other management activities, including prescribed burning, scarification, cultivation, stump removal, herbicide application and drainage improvement. The specific management actions undertaken often vary with the site, although in earlier times, 'blanket' silvicultural management actions were undertaken on many different kinds of sites.

Nursery stock, wildings, and cuttings can all be planted. Only certain species such as cottonwoods, poplar, and willow will grow from cuttings and then the site has to remain moist for a number of weeks. Wildings are rarely planted any longer, but they are used when appropriate nursery stock is unavailable. By far the largest proportion of planting operations use nursery grown planting stock, often grown in tubes or small containers that can be planted easily. In more intensive operations, the planting stock may be genetically improved or cloned through tissue culture.

Seeds may be applied aerially or on the ground. This approach produces a forest with a natural appearance but does not give the manager much influence over stand density. The method is also prone to a higher rate of failure than planting followed by tending; adverse weather conditions are usually responsible for seeding failures.

Today these techniques are still widely applied but with significant modifications to better suit the objectives of ecosystem management. There is a trend to increase the amount of natural regeneration, to match tree species to site conditions, to pay close attention to matching areas with seed source, to minimise the use of herbicides and pesticides, to avoid making heavy modifications to the site, to make silvicultural prescriptions before the harvesting in order to better integrate harvesting and regeneration techniques, to leave more organic matter on the site, and to accept a higher percent damage to seedlings due to natural causes.

2.6 Overview of Other Management Techniques

There are other management techniques used to control regeneration and the stand development. They include prescribed burning, the application of herbicide and insecticide, and thinning. The use of these techniques has changed significantly in the last decade, particularly as the regions have attempted to find ways of implementing ecosystem management.

Prescribed burning is the deliberate use of fire as a silvicultural technique to facilitate the regeneration of forests. In the past it was widely used as a means of reducing the amount of wood debris after harvesting. Under ecosystem management, fire is used to meet a broader set of objectives and its use is generally shifting to areas where fires were a dominant factor in forest development. In areas where fire is frequently used as a site preparation technique, different harvesting techniques will reduce its use substantially. In other areas where fire suppression has been practised for almost a century, the use of prescribed burning is seen as the most reasonable alternative for ecosystem management - i.e. the mimicking of natural disturbances and the reduction of insect/disease outbreaks.

The application of herbicides has also been a widely used management techniques in conjunction with the clear-cut harvesting system. Under ecosystem management the use of herbicides could be reduced since the concerns for biodiversity and wildlife habitat could be ranked as a higher priority than management for timber. However with the adoption of modified clear-cut harvesting the use of herbicides might still prove to be necessary on the sites with high productivity, otherwise forest regeneration might prove to be all but impossible.

The use of insecticides was also part of the traditional forest management system, but this has become increasingly socially unacceptable. Recognising this researchers made significant efforts to develop biological control agents that would have less risk attached to its application. For example in some of the boreal forest regions, the biological control agent *Bacillus thuringensis* is now used to control spruce budworm outbreaks, replacing the chemical control agents.

Thinning is the practice of removing only a portion of an even-aged stand to control its density and capture wood fibre that would otherwise die and be returned to the site. Thinning may be undertaken when a stand is quite young. Such an operation (pre-commercial thinning) is often carried out with a bulldozer or tractor in natural stands and does not yield any timber products. Plantations may be thinned by removing every third row or by removing individual trees from all rows. When the stand reaches an intermediate age, thinning often yields some timber products such as pulpwood or posts. Commercial thinnings, as these are called, maintain a high level of growth in the stand and speed the development of more valuable timber products such as sawlogs or veneer bolts.

2.7 Land Use Planning and Ecosystem Management

As described earlier, ecosystem management operates in the context of land use planning. A chief motive for the development of ecosystem management was the desire to find a way to manage ecosystems without having to separate human uses from biological functions of the rest of nature (Franklin 1992). Thus we would not have to divide the landscape up into single discrete zones; for example, wilderness areas, parks, commercial tree plantations, wildlife zones, and many others. Nonetheless social choices expressed through political processes in many regions have determined that a certain amount of zoning will occur since some ecological values conflict with any amount of human activity. Conversely certain human activity, such as timber extraction, with its often associated clearcutting, plantations and pesticides, conflicts with many option, bequest and preservation values. Therefore ecosystem management has to work with the constraints imposed, particularly at the landscape scale (the forest unit) by the use of zones. Land use planning exercises must ensure that single use zones for nature protection or timber extraction are effectively situated in the landscape by accommodating ecosystem management principles (Hopwood 1991).

Land use planning will be influenced by many factors including: biological productivity, uncertainty and risk, financial feasibility, community sustainability cultural acceptability and political expediency to name but a few. Since ecosystem management is implemented in the land use planning context, all of these factors have an influence on implementation. Within an overall land use framework designed to optimise the compromise between the principles of ecosystem management and human economic activity, there are likely to different levels of management intensity applied. Although these intensities of management form a continuum, it is most helpful to discuss three separate intensity levels: extensive, intermediate, and intensive.

It is most common to describe management intensities in terms of timber management only. This implies that areas managed for other uses such as wildlife habitat or recreation are extensively managed. However, under ecosystem management, it is more appropriate to consider management intensity to be proportional to the level of human intervention. For example, if prescribed burns are set frequently to promote animal browse production, then this level of management should be considered intensive.

Extensive Management

Extensive management is the term used to describe management situations with very little human intervention after timber harvesting. Extensive management also implies low levels of financial investment to produce the next timber crop or some other value, such as recreation. Generally, there is little post-harvest control over the species, density, and structure of the next forest. The rotation is usually longer and timber yields from final harvest are usually lower.

In the context of sustained yield timber management, extensive management may be undertaken to minimise costs, with other management objectives being less precise or non-existent. The next intervention in the forest is determined by market and technical factors. In other words, a cut-and-run approach to forestry used be classed as extensive management (although the use of the term "management" may be questioned).

If extensive management is defined in terms of low human intervention, then it is an appropriate intensity of management to employ within an ecosystem management framework. However, within this new framework, the focus or objective is now to mimic natural disturbance patterns and maintain the functioning of ecological processes. Extensive management would be consistent with objectives such as protecting representative landscapes and producing forest stands with an essentially natural structure.

Intensive Management

Intensive management is said to be practised when there are frequent management interventions and consequently a significant level of human modification to an area. Intensive management is usually driven by a single well defined objective such as maximising the timber yield, maximising economic efficiency or maximising recreational opportunities. However, objectives are often more complex. For example in maximising timber yield, the timber or biomass plantations have been used to help meet other social or environmental objectives such as employment programs, soil conservation, and site reclamation.

With respect to maximising timber yield or economic efficiency for timber production, intensive management usually means there is a significant amount of post harvest control over species and structure. There are usually several post harvest interventions under an intensive forest management regime. These interventions include combinations of site preparation, planting, competition control, stocking and quality control measures, and growth enhancement. The forest rotation is usually significantly shorter in intensively managed plantations and there is higher productivity as defined by timber yields for lumber and pulp or biomass for energy plantations. In almost all cases intensive management requires either a land use zone or well defined ownership rights in order to protect investments made through stand management interventions. The land on which this type of management occurs is typically high in soil productivity and close to mills. This style of management is frequently found in the US South and on private lands in the western portions of North America.
There is considerable debate as to whether intensive management for timber constitutes an ecosystem management approach. Some industrial foresters prefer to call the new approaches that include ecosystem management principles as 'modified plantation forestry' (Atkinson 1990, Hopwood 1991).

Intensive management to promote forest-based recreational opportunities could take the form of enhancing wildlife viewing opportunities, the removal of dead and diseased trees near campsites and trails, and improving fishing opportunities. Ecosystem management would require limiting human activity levels to those which do not degrade the site (i.e. carrying capacity) and avoiding imbalances in the types of non-timber products created in the forest.

Intermediate Management

Intermediate management represents a middle ground between extensive and intensive management. As such, it is difficult to define in precise terms. However, it is often applied when there are multiple management objectives for a given area. In order to facilitate this approach, institutions frequently zone areas of compatible uses. The management approach also implies more complex institutional structures and the use of multi-stakeholders groups to make decisions.

This intensity of management is currently prevalent on publicly owned land in most regions. It is also widely practised on private land in the Scandinavian region and is becoming more common on private land in North America.

In many cases, ecosystem management moderates the level of human activity through consensus-building processes.

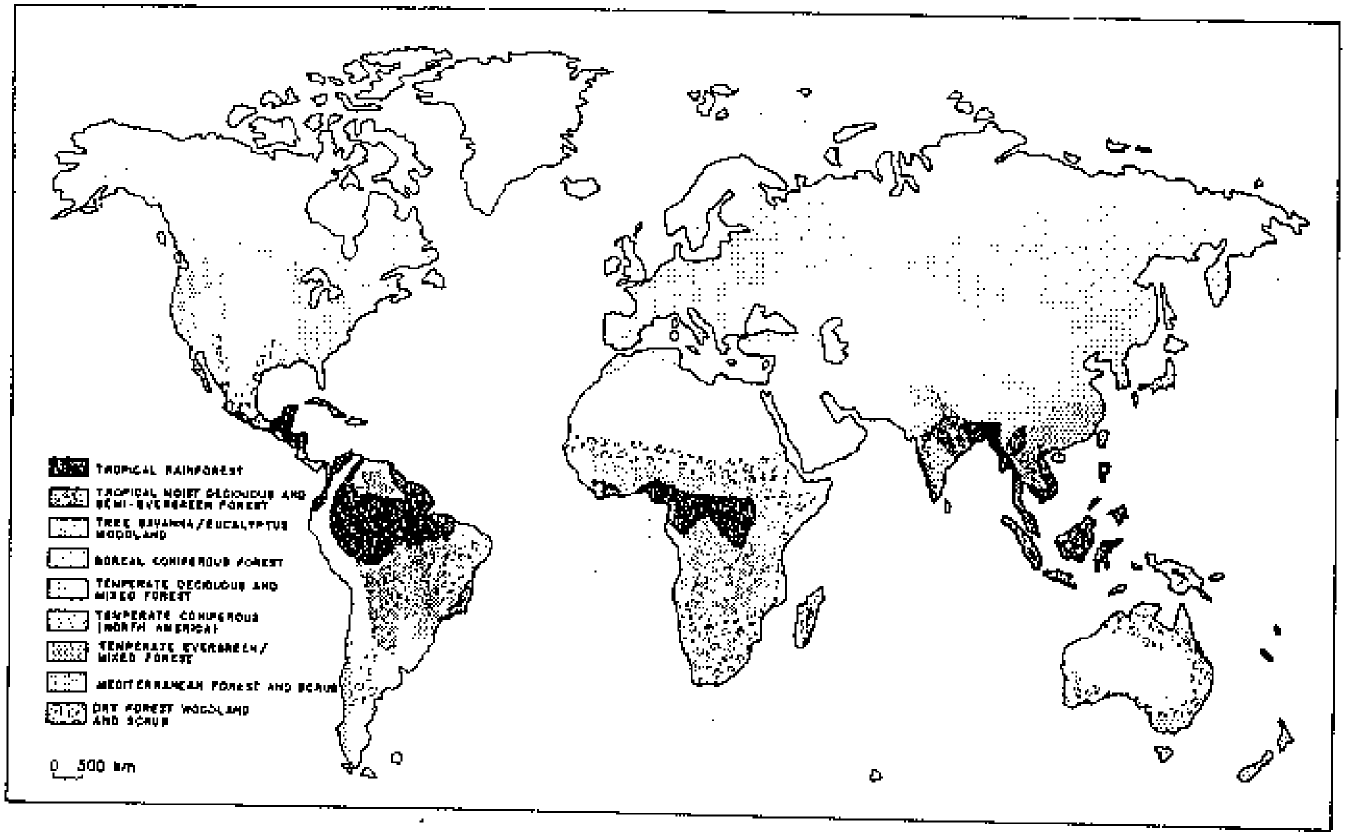
3.0 Forests and Forest Management in the Northern Boreal and Temperate Forest Regions

The management approaches applied in the Northern Hemisphere temperate and boreal forests are designed to correspond to characteristics of the species and forest type to which they are applied. Thus, regional variation in forest type translates into variances in forest management systems. One purpose of this report is to describe the primary management systems used in these forests and describe how a shift to alternate management systems is expected to affect the sustainability of the forest and commercial forestry operations. This task can only be accomplished if the forests are differentiated in a manner that facilitates discussion and comparison of the management systems yet minimises intra-regional variation. These requirements were balanced against various constraints to select a set of regions to be used in this part of the project. The primary limitations were the manner in which data are compiled and the time and resources available to the researchers.

The classification used in this report is not entirely a natural one. The regions are broadly defined by major forest types and then adjusted to meet political boundaries, i.e. state, provincial, or national boundaries. This is necessary since the statistics used to describe the areas and derive the indicators of sustainability are commonly compiled by political jurisdiction, not by forest type. Where a jurisdiction has two forest types, the forests have been zoned according to the major forest type within that jurisdiction. For example, Alaska has been included in the western temperate rainforest region, rather than in the northern boreal region since the major volume of standing timber is in the coastal region of the state, even though the majority of the forest area is boreal.

After considering these factors, the researchers decided to divide North America into four forest regions: North American boreal, Eastern temperate, Southern temperate, and Western temperate. Eurasian forests were divided into three regions: The Nordic countries, Europe, and Russia (Figure 1).

Figure 1. Major Forest Regions of the World



3.1 North American Boreal Forest Region

3.1.1 Geographic Location

The boreal forest zone stretches across the northern latitudes of North America, Europe, and the former USSR. At its northern extremes, it merges into the taiga and tundra while at its southern border it is contiguous with temperate forests. For this project, the forests of all Canadian provinces and territories, (except British Columbia) will be treated as the North American boreal forest. This assumption means that the boreal zone includes significant areas of temperate forest in southern Ontario, Quebec, and the Maritime provinces as well as montane forests in Alberta. On the other hand, boreal forests in Minnesota, Michigan, Alaska, and British Columbia are excluded. In Alberta the forest is assumed to be boreal and therefore the northern Rockies forest type is combined with the boreal region. The temperate hardwood forests of southern Ontario, Quebec, and the Maritime provinces were not separated from the northern boreal forests of those provinces.

3.1.2. Major Forest Types

The boreal forest is typified by black spruce (*Picea mariana* (Mill.) B.S.P.) which inhabits both lowlands and well-drained upland sites. Other widely distributed softwoods include balsam fir (*Abies balsamea* .(L.) Mill.), which is of major commercial importance only in the eastern portion of the region and white spruce (*Picea glauca* (Moench) Voss), most importance in the central part of its range. Jack pine (*Pinus banksiana* Lamb.) prefers relatively dry, sandy sites and its prime range covers Quebec through to Saskatchewan. In the west, it blends into lodgepole pine forests and in the Maritime provinces it has only a scattered distribution. Red spruce (*Picea rubens* Sarg.) is important in the Maritimes and eastern Quebec, but is rare in eastern Ontario and absent further west.

The predominant hardwood species are poplars, particularly trembling aspen (*Populus tremuloides* Michx.) and balsam poplar (*P. balsamifera* L.), and white birch (*Betula papyrifera* Marsh.). They are found throughout the boreal forest but become less common in the northern extremes of the zone.

There are several important species that extend into the boreal zone from the eastern temperate forest. The species that extends furthest north is eastern white pine (*Pinus strobus* L.) with red pine (*Pinus resinosa* Ait.), yellow birch (*Betula alleghaniensis* Britton), and sugar (or hard) maple (*Acer saccharum* Marsh.) penetrating moderately far north.

The main forest types can be distinguished using topographic criteria. Throughout the boreal zone, the lowland sites support virtually pure coniferous forests of black and red spruce with some balsam fir, cedar, and larch. The productivity of these sites tends to be moderate to poor. Upland sites are generally richer and may support either pure species stands, or more commonly, mixtures of hardwoods and softwoods.

The boreal forest is characterised by large scale disturbances, notably fire and spruce budworm. As one progresses from east to west, the climate becomes drier and fire serves as the major natural cause of stand replacement. In eastern Quebec and the Maritime provinces, spruce budworm is more important, although the role of fire remains significant. Species such as jack and lodgepole pine and aspen have traits that enable them to vigorously colonise burned areas, often forming dense, pure stands. Tolerant balsam fir usually forms pure upland stands after an area has been undisturbed for 80-100 years or more. However, it is the preferred host of the spruce budworm and periodic severe infestations remove the entire balsam fir component from the affected forest area. Spruce budworm also defoliates other spruces and will kill these species too. Thus, a severe budworm infestation will remove the entire spruce and fir component, allowing hardwoods and pines to enter.

3.1.3 Past and Present Forest Use

White pine was the first species to be commercially harvested in the boreal forest zone. Starting in the late 18-th century, squared timbers were exported to Great Britain; later rough lumber was shipped to the US. As the pine was depleted, the industry spread westward from Maritimes along the St. Lawrence and Ottawa River drainage systems. By the late nineteenth century, the original white pine was virtually exhausted and the industry turned to spruce, red pine, fir, and hemlock.

As the Maritimes and southern Quebec and Ontario were settled, much area was cleared for agriculture. Settlement was encouraged by land grants, resulting in a high level of private ownership in these regions. In 1843, the New Brunswick government began to lease the harvesting rights on its land, a practice that has been adopted by other provinces and continues to modern days. However, some provinces continued to grant land to individuals for homesteading until the 1930's.

It was not until the pulp and paper industry expanded into northern Quebec and Ontario during the 1910's and 1920's that the northern boreal forest experienced significant exploitation. The industry, along with mining, was viewed as a means of developing the northern hinterland and so was encouraged by provincial governments even until the 1950s. Initially, only black spruce was used, since it is prized for its paper-making characteristics. Large tracts of land were licensed to pulp and paper companies, many of which were owned in part or in entirety by American newspaper firms. The companies often built entire towns for their workforces, and rail and road networks developed.

In Manitoba, Saskatchewan, and Alberta, the Canadian government retained control over natural resources policy until 1930. At this time, the first pulp and paper mill in these three provinces was built in Manitoba but the majority of the industry was based on portable sawmills. Alberta went through an intensive diversification drive during the 1980s, which dramatically expanded the forest industry in that province. However, in Saskatchewan and Manitoba, the industry still consists of a small number of pulp and paper mills.

After World War II, the North American housing boom inspired a proliferation of sawmills throughout the boreal forest zone. These were also encouraged by provincial governments anxious to salvage wood damaged during several years of severe fire. This industry relied on jack pine, black spruce and balsam fir, using white spruce and white and red pine as they were encountered.

Commercial use of the hardwood species was limited until the early 1970's, when waferboard was developed. Also at this time, techniques were developed to use some hardwood in the pulping process. Hardwood fibre imparts some desirable properties to paper and traditional pulp species were becoming scarcer, more distant from the mill, and smaller in size. This trend continued until the industry developed the capability of making pure hardwood pulp. The most recent wave of industrial development has seen the establishment of composite board mills that use "low-grade" fibre, now including white birch (debarking white birch had proved to be an obstacle towards greater use of that species).

The history of the commercial forest products industry in the boreal forest can be characterised as a progression in the use of timber species, so that now the entire range of species is utilised. During the past five years, the supply of softwood has become a significant constraint on industry and timber prices have risen substantially since the 1991 recession ended. Furthermore, private land harvesting has accelerated due to higher prices and greater industrial interest. Since private timber management is largely unregulated, this raises questions about the sustainability of this harvest component.

Most of the boreal forest is now accessible by road. There are pockets of forest in the northern parts of provinces west of Quebec that are unroaded, as is much of the unmerchantable far north. The traditionally positive view of access creation is being replaced by the recognition that access contributes significantly to many land use problems. The loss of remoteness due to access construction has severe negative consequences for the operators of fly-in fishing and hunting camps, First Nations bands that wish to retain aspects of their traditional lifestyle, and the fish and game populations of newly accessed lakes and land areas.

Most land use controversies pit timber interests against tourism and recreation users, although environmental groups have often become involved. There are two principle causes behind the escalation of the frequency of disputes:

1. The shrinking area of commercially desirable, mature forest, especially lands that have not been previously harvested; and
2. the failure of timber companies (and by extension, the provincial governments) to maintain the confidence of the general public in their management of the forest resource.

This situation has forced the timber companies, often due to regulatory action, to modify their approaches to planning and harvesting. At the same time, significant areas of forest land have been withdrawn from commercial timber availability.

Furthermore, First Nations people claim that they have unfairly given up title to large tracts of forest land. They are demanding a package of rights to manage or co-manage the land and to also receive compensation. There has been little progress in settling many of these disputes.

In conclusion, timber companies have become simply one of many forest stakeholders and provincial governments are in the process of devising procedures to allow for effective planning input by all stakeholders. It is not clear how much authority will remain with government or the industry.

3.1.4 Area, Volume, and Harvest Levels

Table 3.1 presents some basic statistics for the boreal forest. These are presented by jurisdiction and totalled in the bottom row. The primary sources of these data were the 1994 State of Canada's Forests Report (Forestry Canada 1995) and the 1994 Compendium of Canadian Forestry Statistics (Canadian Council of Forest Ministers, 1995).

Total land area is the area of all land and water within each jurisdiction. The next column shows the amount of productive forest land, which is land that is capable of growing commercially usable timber and is presently classed as forested. This definition excludes agricultural land but includes recent harvest area. Provinces differ in how they define productive land, which chiefly affects how marginally productive land is treated.

The next column shows the percentage of total forested land owned by private industrial and non-industrial owners. The boreal forest is unique among major North American forest types in that most of it is publicly owned, primarily by Canadian provincial governments. The Yukon and Northwest Territories are owned by the Canadian federal government.

The growing stock is the volume of standing timber, unadjusted for decay and defect (i.e. gross merchantable volume), on productive forest land. Growing stock is affected by depletions, productivity, species mix, and the age class structure of the forest.

The annual allowable cut (AAC) is a short-term measure of the volume of timber that the land owner (or regulator) is willing to make available, under current conditions, from a specific area for a specific period of time (Williams and Tanz, 1994). This volume is a regulatory limit and as such, it only really applies to publicly owned land. Of all the data shown in Table 3.1, the AAC figures exhibit the greatest inter-provincial variation. There are three main reasons for this:

1. The means of calculating the AAC vary widely and depend on assumptions regarding operability, age of harvest, accessibility, growth and mortality, and regeneration practices.
2. The AAC is viewed by some agencies as the upper biological limit on harvesting, whereas others view it as the "average" economically accessible harvest volume. The AAC may be higher or equal to the long-run sustained yield, depending on whether the forest growing stock is larger than that level expected under management in the long-run.
3. Some provinces estimate the sustainable harvest level from private land and include it in the provincial AAC while other provinces exclude the private land harvest volume.

The actual harvest data include roundwood and fuelwood cut from all ownerships, although in most cases the private land harvests are rough estimates. Note that the Yukon Territory has no established AAC.

TABLE 3.1 OVERVIEW OF FOREST SIZE AND HARVEST LEVEL IN EACH BOREAL FOREST JURISDICTION.

Province	Total Land Area (million ha)	Productive Forest Land Area (million ha)	% Private Owned	Total Growing Stock (million m3)	AAC (000 m3/year)	Actual Harvest (000 m3/year)
Newfoundland & Labrador	40.6	11.2	1	532	2987	3131
Prince Edward Island	0.6	0.3	92	26	441	534
Nova Scotia	5.5	3.7	69	262	5275	4585
New Brunswick	7.3	6.0	51	646	10898	8959
Quebec	154.1	53.3	11	4302	56500	34604
Ontario	106.9	40.7	11	3783	47381	25432
Manitoba	65.0	15.0	5	946	7795	1539
Saskatchewan	65.2	12.0	1	896	7068	4433
Alberta	66.1	21.2	4	3123	23437	14183
Northwest Territories	342.6	13.7	0	479	301	203
Yukon Territory	48.3	7.4	0	638	na	193
Total Region	940	184.5		15633	162083	97796

3.1.5 Sustained Timber Yield Management in the Boreal Region

Sustained timber yield management in the boreal region is characterised by clearcutting. The primary reason for this is that all of the commercially important species except white spruce grow best as even-aged stands. Thus, clearcutting is often silviculturally desirable in the boreal zone.

After harvest, some form of site preparation is often performed, especially if regeneration is to proceed by artificial means. Light site preparation includes dragging chains or barrels to expose mineral soil whereas bulldozing and trenching may be performed where heavier effort is required. Prescribed burns are sometimes used.

Natural regeneration offers advantages in that it is low cost, results in stands with a "natural" appearance, and ensures that the next stand has a genotype that is compatible with the local climate and site. On the other hand, the species composition of the next stand depends on the species of trees adjacent to the site as well as the species of the just-felled stand. A final drawback of natural regeneration is the opportunity cost associated with longer rotations and lower yields than plantations would achieve.

One of the main challenges for boreal forest managers is to produce second growth stands that maintain the coniferous content of the preceding ones, especially on more productive upland sites. Herbicides have been widely used to control competing vegetation but this practice is coming under pressure from the public and from environmental groups. There are few other economically viable means of controlling competition. Manual methods of release and even the use of sheep have been tried but are not feasible on any significant scale.

Jack pine and black spruce are the species most commonly seeded in the boreal forest. Jack pine seeding operations have a high success rate, especially if the site is fairly clear and if seed is applied in two successive years. On the other hand, success with black spruce has been generally poor.

Plantations provide a manager with influence over the initial species and density of a stand. Another advantage of planting is that it will accelerate the development of the next stand. This creates an increase in timber supply and it also "greens up" cutover areas more rapidly than other regeneration methods. One or two applications of herbicide are common to ensure that the planted stock escapes from its competition. Most plantations in the boreal forest area are not managed once they have become established because the economic returns are commonly felt to be too low. As a result, many planted areas receive ingrowth from natural sources and so become mixed stands. Exceptions can be found on private land in the Maritimes (notably New Brunswick) and in some areas in Alberta. These intensively managed plantations are more likely to be single-species stands that will be thinned two or more times before the final harvest.

3.1.6 Ecosystem Management in the Boreal Region

Ecosystem management has not been undertaken in many boreal forest areas. Therefore, there are no *ex post* observations or data available. However, the application of ecosystem management is becoming a topic of discussion among boreal foresters. Two examples are described in Boxes 1 and 2: the White River and the Seine River. In the White River area, the Ontario Ministry of Natural Resources and Domtar Inc., the co-managers of one management unit in Ontario, have devised a management plan for the forest based on ecosystem management principles. This may be considered to be a general model for the boreal application of ecosystem management.

The underlying objective of the plan is to conserve or maintain the biodiversity of the forest (Eason, 1994). The management plan approaches this task by considering a range of wildlife species that is much wider than is usually considered. A second assumption is that wildlife populations are allowed to deviate from present levels within certain percentage ranges, reflecting the disturbance oriented nature of the forest and the attendant wide fluctuations in species populations over time. Thirdly, management is not intended to maximise biodiversity, but rather provide a range of diversity across the forest landscape.

The management approach is distinctive from usual approaches in its use of coarse and fine filters. Presently, most boreal forests are managed using featured species guidelines (the 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 will be put at risk. The reason for the risk is that managers will not be paying attention to these other species, since their welfare is not part of the structure of management goals. An alternative approach is the idea of the coarse filter, which proposes to 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 would argue that a combination of fine and coarse filters will be most appropriate in most situations. The coarse filter looks after many of the smaller organisms while the fine filter focuses on larger species that require a mixture of habitats.

The coarse filter proposed on the White River Forest uses forest ecosystem class (FEC), age, and stocking characteristics of areas within the forest to define ecosystem types. For example, the management plan stipulates that no FEC type should increase or decrease by more than 50% from the baseline area, which was set on the basis of pre-harvesting inventory data. In this way, disturbances are allowed to cause large changes in the area of different ecosystem types but the manager will seek to prevent or correct larger shifts. The plan also calls for the retention of at least 12.5% of each FEC past the age of rotation on each 100 km2 area (which was estimated to be the magnitude of historical fires) and 25% of each FEC should be left past rotation on each 1000 km2 area. This example illustrates how different spatial scales are being recognised within the management unit.

Some background work was also done on the periodicity of fire in the Forest. Average fire return times were estimated at 75-125 years (Wedeles and Eason, 1995), with few areas experiencing more than 200 years without fire. The following steps were taken in order to best determine how to best mimic natural disturbances with forestry operations:

- the major forest characteristics affected by forestry operations and natural disturbances were identified;
- the natural pattern for each key forest characteristic was examined;

- the effects of current management practices on natural patterns was determined; and
- changes in management actions that would maintain a more natural pattern were identified.

Box 1. North American Boreal Region - White River Forest, Ontario

The White River Forest covers 607 400 ha in north central Ontario and is jointly managed by the Ontario Ministry of Natural Resources and Domtar Forest Products Ltd. There, resource managers have begun to practice forest management based on ecosystem concepts. This shift in approach came about as they debated how to comply with the provincial government's decision to adopt the principles of ecosystem management, how to best support a new provincial wildlife strategy and how to meet the Canadian government's commitment to conserve biodiversity - the Rio Convention. Data for this case study come from internal reports written by and conversations with G. Eason in 1994 and 1995.

The natural disturbance factor that has been subject to the most control is fire and so the desire to mimic natural fire patterns formed many of the new management guidelines. Ecosystem abundance is to be monitored using 1000 km2 blocks, which is based on the area of ecological zones within the forest and the order of magnitude of historical fires.

Resource managers recognized that the standard Forest Resource Inventory (FRI) was unsuited to ecosystem management and so the FRI was re-cast in terms of the provincial Forest Ecosystem Classification (FEC) system. The 1963 version of the FRI, which represented the forest as it was before significant harvesting, was used as the baseline for the ecosystem maintenance guidelines. These guidelines are that no FEC type should increase or decrease by more than 50% from its baseline abundance in a 1 000 km2 block and any stand conversion should be in the direction of natural forest development. This will allow cover type abundance to fluctuate over time as would occur after large fires, yet it prevents the decline of any single cover type. The retention of white spruce seed trees is emphasized to maintain the species and provide supracanopy wildlife habitat structure.

Guidelines were also developed for forest age structure. In each 1 000 km2 block, 25% of each FEC type is to be older than the estimated fire rotation age and, within each 100 km2 block, 12.5% 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. Draft guidelines were developed for stand density and will be implemented when a GIS system is available.

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 forestry practices. These include leaving snags, leave 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.

Measures have also been taken to use a wider range of harvest block sizes (cuts average about 1 km2 but range from 0.5 km2 to 5 km2), 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-lovers.

The expected impact of these measures is to reduce the wood supply volume by roughly 25% from the theoretical maximum, largely due to the maintenance of older stand types. Reserves and by-pass areas already reduce the harvest by 15% from the theoretical limit. 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 favourably received by Domtar.

Box 2: North American Boreal Region - Seine River Forest, Ontario

The Seine River Forest is a 270 000 ha forest management area in Northwestern Ontario, located along the central southern margin of the North American boreal forest. The forest is dominated by older jack pine stands, which is fairly typical of the region. At present, forestry is conducted in a fairly standard manner: the exclusive use of clear cutting is followed by site preparation, planting, and tending.

Gooding (1995) used a simulation model to compare the impacts of continuing to use this approach versus adopting a mixture of clear cutting and alternative silvicultural systems featuring intermediate harvests, natural regeneration and an extensive permanent road network (Wedeles et al. 1995). These alternative silvicultural systems were primarily applied to older, more open stands or juvenile pine-spruce stands. Both of these forest types have trees that are relatively windfirm. Other natural boreal forest cover types grow rather densely and are very susceptible to windthrow following intermediate harvests (Wedeles et al. 1995; Ruel 1995).

Two main scenarios were run: (a) unlimited clearcutting subject to timber sustainability: and (b) the maximum sustainable harvest obtainable with a set of alternative harvesting prescriptions. Although option (b) did not include objectives regarding ecosystem sustainability, it can be considered to represent the harvesting approaches that would be taken under ecosystem management.

Over a 200 year time horizon, option (b) resulted in higher total forest operating costs (i.e. harvest, transport and silvicultural costs) compared to the other two options. However, silvicultural costs fell as the need for planting declined.

The adoption of alternative harvesting methods reduced the annual allowable cut from 313 000 m3 in option (a) to 238 000 m3 in (b). In contrast, the area cut annually in option (b) was 3 600 ha compared to 2 300 ha under option (a) because patch sizes were smaller under ecosystem management.

On the other hand, ecosystem management created a greater diversity of forest stand ages and structures compared to the standard management strategy.

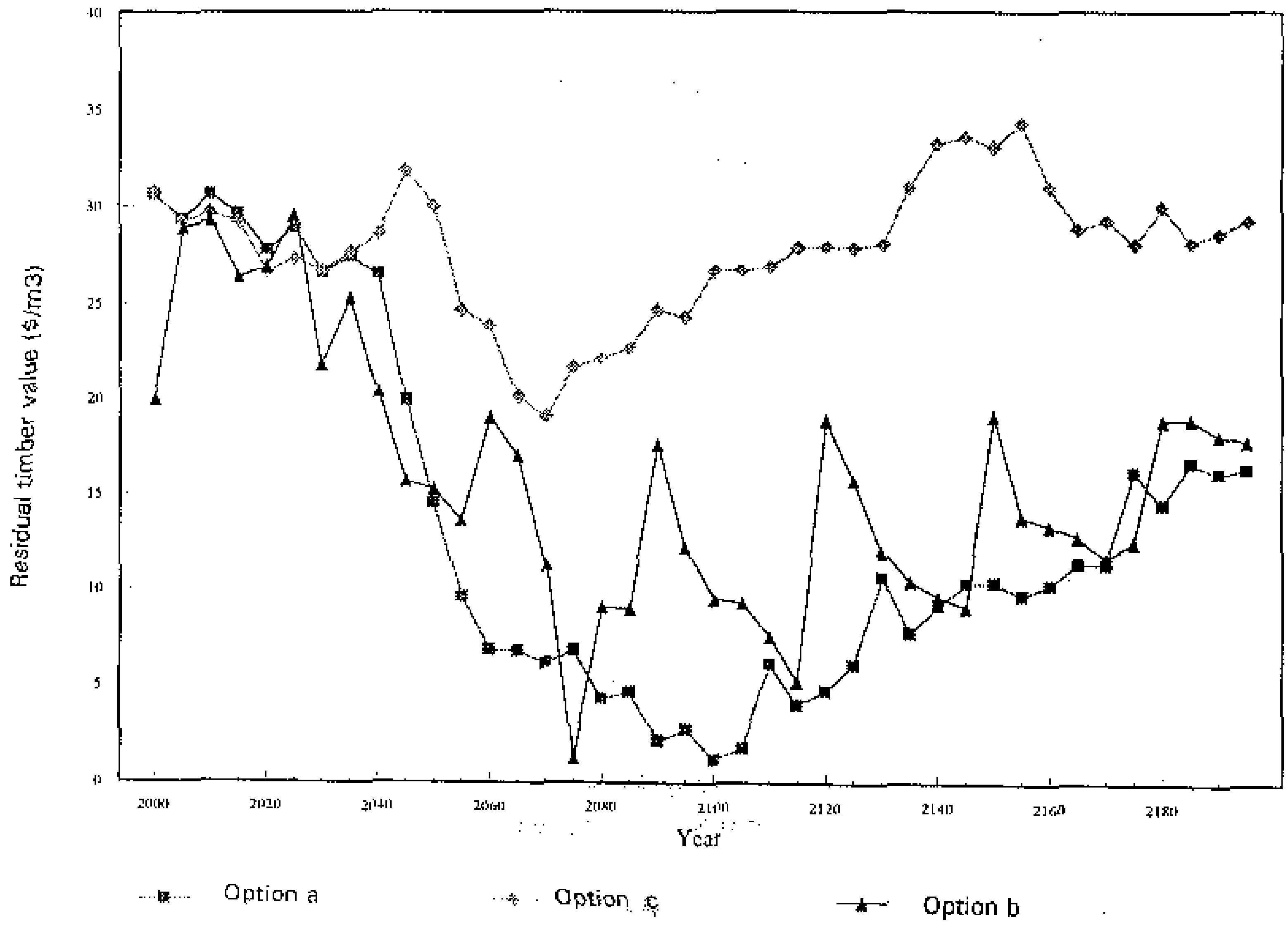
Under option (b), forestry activities were dispersed across the landscape, which may create land use conflicts. Coupled with the reduction in allowable cut, this suggests that the social costs associated with ecosystem management may be a more important consideration than the increased timber production costs. These unfavourable socio-economic costs of ecosystem management might be mitigated by the increased use of labour-intensive operations such as thinning.

The amount of clearcutting modelled in option (a) is unrealistic since it ignores many of the numerous guidelines and regulations that protect wildlife and other forest values (Koven and Martell 1994). Option (c), clearcutting at the harvest level obtained under option (b), is likely to be closer to actual harvest levels. As Figure 2 shows, the average results are intermediate between those of options (a) and (b).

The technology and increased operating skill required to properly conduct the intermediate harvests in the ecosystem management scenario can also be applied to thin young stands. The volume recovered from thinnings can mitigate the forecast reduction in allowable cut under ecosystem management. Thinned stands will also develop windfirm characteristics thus increasing the range of stands eligible for the application of alternative silvicultural systems. This should improve the flexibility of future operations and may increase the allowable cut.

A greater reliance upon thinning to supply wood from small diameter trees will increase wood costs (Mellgren 1990). Furthermore, the forest may not have enough stands eligible for thinning in the right time period to have the desired effect upon long term wood supply.

Figure 2. Net Timber Value Over Time under Options A, B, and C



3.2 Eastern NA Temperate Forest Region

3.2.1 Geographic Location

The Eastern temperate hardwood region spans the north-eastern United States, including Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio, Kentucky, as well as the mid-Atlantic seaboard and New England states extending north from and including West Virginia and Maryland. This forest region is characterised by hardwood species such as sugar maple (*Acer saccharum* Marsh.), beech (*Fagus grandifolia* Ehrh.) and yellow birch (*Betula alleghaniensis* Britton) in the north and various oak (*Quercus* spp.) and hickory species (*Carya* spp.) in the south and west. The softwood component of the forest tends to be spruce (*Picea* spp.) and balsam fir in the north and various pines (*Pinus* spp.) in the southern portions. This region is equivalent to the North Region as defined by the US Resources Planning Act. There are two portion, the north-central and the north-east. (For the purposes of this project the Great Plains States of the Dakotas, Nebraska and Kansas will not be included since they do not contribute significantly to the current or future timber supply.)

3.2.2 Major Forest Types

The north-central is dominated by the oak-hickory which includes a mixture of species groups: elm-ash cottonwood on the lowlands: beech-sweetgum-pin-oak flats; mixed pine-hardwoods on the dry soils and the maple-birch cherry on the remainder. Some of the oak dominated forests of the north-central portion extends into the southern areas. It is not unusual to find as many as 15-20 commercial species on a 5 ha area.

The north-east includes the beech-birch-maple or northern hardwoods, the spruce-fir forests and the white pine-hemlock-hardwood forests. The volumes of hardwoods and softwoods are roughly equal. The softwoods are found mainly in Maine and New Hampshire and the maples (roughly 40% of growing stock) dominate the hardwoods in the states immediately to the south.

3.2.3 Past and Present Forest Use

The current structure of the forest in the eastern US region is largely the result of human activity beginning in the 1500s with Native Americans (Williams 1989). They used fire throughout the region to move game animals, open forest understories and clear land for agriculture. European activity starting in the late 1700s and initially utilised Native American methods for clearing forests for agriculture. Much of the land cleared was abandoned in the 1800s and returned to forests as fertility declined. Woodlands that were not heavily cleared were invariably heavily cut to provide the timber needs of the expanding population, High grading, grazing, and burning of the woodlands continued into the depression years of the 1930s, when forest products sometimes constituted a medium of exchange in rural communities.

In the north-east the pattern of forest use resembles the north-central has become 'resaturated' with forest land. Recent estimates indicate the region has gained over 600 000 ha during the past decade, suggesting the cessation of agriculture slightly outpaces losses to development. However in other states the pattern is the reverse. In one state, Missouri, 700 000 ha of forest land was converted to grassland between 1959 and 1972. This shifting from forest to agriculture and sometimes back to forests is unusual in the North American context and makes this area unique.

Today, in the north-central and north-east subregions, management efforts to try and recreate the older forest types are frustrated by the lack of markets for small and low quality logs and the economic pressure is often to high grade the stands. However with the significant human pressures for recreation and second homes in the rural areas, and changes in government tax policies (Ireland and Maass 1994) timber management for pure economic returns is becoming impractical and less attractive.

3.2.4 Area, Volume and Projected Harvest Levels

The USDA (United States Department of Agriculture) defines productive forest land in terms of its ability to support annual growth rates of the forest exceeding at least 1.0 m3/ha/yr. The size and location of the productive land base can change over time driven by changes in prices and technology. According to this definition, nearly 38% of the total land base is considered productive in this region and there are indications that the growing stock is increasing. The growing stock numbers for the region indicate the total volume that could be removed for wood processing, without considering the annual growth added of the forests. The annual harvest numbers if compared to the total growing stock and assuming no annual increase in growth, gives some indication of whether the harvest level is sustainable, from a timber point of view.

TABLE 3.2 OVERVIEW OF FOREST SIZE AND HARVEST LEVEL IN THE NORTHEAST US TEMPERATE FOREST REGION.

Sub-region	Total Land Area (000 ha)	Productive Forest Land Area (000 ha)	% Private Owned	Total Growing Stock (million m3)	AAC (000 m3/year)	Actual Harvest in 1991 (000 m3)	Average harvest volume (m3/ha)
North-east	51,225	32,165	93	3,756	-	62,430	-
North-central	115,890	31,720	72	2,839	-	54,704	-
North total	167,115	63,885		6,595	-	117,134	-

(Source: Powell et al., 1994)

Land ownership in this region is unique. The north-eastern forests are owned almost exclusively by private entities (93%) ranging from the large industrial holdings (22%) to small woodlots. Tract size of nonindustrial ownerships continues to decline to an average size of 4 ha.

In the north-central forest while only 72% of the ***productive*** forest land is privately owned (Waddell et al 1989) nearly 90% of the ***commercial*** forest land is privately owned. Most of this land is about equally split between farm and other private owners. The forest industry has increased its acreage to about 10% of the total in the last decade. This suggest issues of forest ownership is extremely important in examining future wood supplies.

A significant trend in recent years is the shift of forest ownership to the nonfarm sector. Individuals in this group hold land for a variety of reasons including speculation, recreation and second homes. Timber production is often of minor concern. On the other hand many of these owners are professional people who are interested in proper management techniques being applied.

Less than 7% of the region's timberland is publicly owned. These lands are relatively small and are usually fragmented with private inholdings. For example, most of the national forests within the region own less than 50% of the land within their boundaries. Similiarly state lands in the southern area are also scattered. This makes it essential to have private landowner participation in efforts to switch to ecosystem management.

3.2.5 Sustained Yield Timber Management of the Eastern Region

The harvesting/silvicultural system most often applied in this region was partial cutting, or highgrading which in effect means taking the most valuable trees. This exploitative logging of forests had no silvicultural intent, habitat fragmentation was rampant and changes in land use, particularly from forest to agriculture and back to forests again, was common (Barrett 1995). In contrast to other regions this type of management received less criticisms because artificial silvicultural practises such as mechanical site preparation and planting monocultures of genetically improved trees have never received widespread application in the north-east subregion.

Today the growing stock of hardwoods in the north-east subregion is increasing and from the timber point of view seems to be underutlized. However, the result is an overstocked forests where the quality of desirable stems for timber harvesting is increasingly diminishing (Ireland and Maass 1994). From a silvicultural point of view it means that tree species such as white pine, paper birch and oaks are being replaced with later successional species such as the ubiquitous red maple, whose per cent forest cover has increased by 26% from 1970 t0 1980. For the softwoods in the north-east subregion, particularly in Maine, traditional management has led to a rapid decline in commercial volume largely due to the spruce budworm outbreaks and intense utilisation of the spruce-fir resource (Barrett 1995; Irland and Maass 1994). This could lead to a reduction in softwood timber volume harvested as least in the shortrun.

3.2.6 Ecosystem Management in the Eastern Region

In response to the criticisms of forestry practice in the northeast subregion, there has been a call for ecosystem management. Some key principles in this new approach include patterning silvicultural systems after natural disturbance, restoration of species and age diversity and widespread retention of reserve trees, preservation of rare species and enrichment planting to restore depleted species, longer rotations and limited whole-tree harvesting.

The forests in the eastern region lend themselves well to managing for biodiversity as well as high value forest products. With appropriate modifications, silvicultural systems traditionally used for wood production can enhance diversity more often than they conflict. For example, conventional systems can be modified to now include *wildlife clearcuts* that leave scattered residual trees (both living and dead) for highly exposed perches and cavity users. *Low density wildlife thinnings* and *open wildlife shelterwoods* designed to promote development of understory vegetation, mesh with systems required to regenerate species of intermediate shade tolerance (such as white pine, and yellow birch) as well as heavy crown thinnings used under crop-tree systems. Irregular shelterwoods or selections systems provide permanent vertical structure if some low-quality trees are retained. Areas disturbed during logging (such as skid trails, landings, and roadsides) can be maintained semipermanently in early successional grass or forb communities (Barrett 1995). Overall, this new approach means artificial regeneration practices will decline, and more emphasis is being placed on protecting advanced regeneration during harvesting operations (Ireland and Maass 1994).

However even with the renewed emphasis on biodiversity there are still areas of potential conflict in this region between the practitioner of ecosystem management and the clients he/she serves. They include: 1. The use of moderate to heavy disturbances to produce early successional forest types (e.g. aspen, birch, cherry, oak), which is a form of even-aged management, is not popular. 2. The aesthetic appearance of heavy disturbance areas is objectionable to many recreationists and many small private landowners. 3. The notion of green tree retention, i.e. leaving some large trees on site, may not be accepted by the private landowners who wants to maximise timber yields or to the forest worker for whom these tree pose a real safety risk.

Recent surveys indicate that the non-industrial landowners, who are a sizeable portion of the land managers in the region, now have an interest in ecosystem management. This is in contrast to their attitudes in the 1970s when these landowners expressed little interest in any commercial tree harvesting; instead they valued their forest primarily for aesthetic and recreational reasons.

In the north-central subregion a vociferous conflict over the role of clearcutting in sustained yield timber management has also taken place. Largely in reaction to indiscriminate high grading and commercial clearcutting the shift by state agencies has been towards partial cutting techniques, usually selection cutting. The federal agency, the USDA Forest Service, has also moved to more partial cutting in recent years primarily due to ecological concerns such as biodiversity and habitat fragmentation. The other major land managers in this subregion, the small non-industrial landowners, frequently have not traditionally clear-cut because amenity values are of equal or greater importance than commercial wood values.

Overall ecosystem based management seems well suited to forest management in the eastern region. The federal and state agencies have already introduced this approach and the important non-industrial landowners also seem willing to embrace this type of management (see for example Box 3).

Box 3. Eastern North America Region - Haliburton Forest and Wildlife Reserve, Ontario.

The Haliburton Forest and Wildlife Reserve, a non-industrial private land of some 20 000 ha, is located in the eastern hardwood forest of North America. It had a long history of high-grade logging up to the 1960s when the commercial timber supply was finally exhausted.

Rather than wait for the next commercial crop to grow, the new proprietors decided on a two prong strategy: to diversify the type of products to include recreation with wood production and to adopt an ecosystem management approach to forest management.

The ecosystem management approach means that the timber is harvested differently both in term of the quantity or wood removed in each cutting cycle and more importantly the quality of the trees removed. The average volume of wood harvested has decreased and the quality of wood removed has decreased significantly in attempts to restore a healthier and more diverse forest. Of course this has implications in terms of planning, roads, timber harvesting systems, and silviculture.

Planning is now far more complex. First, there is a lack of growth and yield data as a basis for projecting timber inventory for forest under ecosystem based management. This means the landowner must use an area based approach to determine the harvest volume or set up permanent sample plots for an improved basis for calculation of harvest levels. In addition, the recreation and outdoor education program is critical for reducing the pressure on the operation in meeting it financial obligations,. The users of the forest area which includes: mountain bikers, campers, hunters, cross-country skiers, snowmobilers, birdwatchers, fishermen, musicians, high school to university groups and many other outdoor enthusiasts all contribute up to 80% of the annual revenue of the operations. The annual cost of planning has risen by over 200% in order to maintain communication between management and user groups.

In order to distribute the harvesting operations spatially, more road access had to be developed and the average annual cost of road construction has risen by 300%. The cost of keeping more roads active has meant an increase in maintenance cost of at least 100%. Since the roads are multi-purposed some of the costs can be assigned to other forest uses besides timber operations.

The timber harvesting system is currently a line skidder operation and there is significant experimentation with newer techniques already developed for logging in Europe. The overall emphasis is to rely on the skidders for longer skid distance and therefore build less permanent roads. There is an emphasis on minimising soil compaction by harvesting only at the time in the year when soil it either frozen or when dry. Horses are also used in riparian areas to do selection cutting. They have minimal impact on soils in the harvesting operations. The increase in costs due to change in harvesting operation is the range of 100% to 200%.

The silvicultural systems employed emphasises diversity of tree species, wildlife habitat improvement and improvement in wood quality in the residual stand. The emphasis on stand diversity ensures that minor species can play an appropriate role in ecosystem management and provide different products for the next generation. In order to protect wildlife there are special wildlife trees left for birds of prey and cavity nester and small mammals . Trees are harvested about every 20 years and as the tree quality improves on the remaining forest the type of wood product produced will shift from firewood and low quality sawlogs to high quality veneer and sawlogs. The costs of changing to this type of silvicultural system are significant.

The total wood costs implications range from 300% to 500% in present logging operations and this is attributable to higher access costs in order to accommodate low impact logging and the much lower volume per hectare, at least in the short run.

3.3 Western NA Temperate Forest Region

3.3.1 Geographic Location

This region, which comprises the province of British Columbia and the states of Oregon, Washington (the northern Rockies), California and Alaska, and the states of Arizona, Colorado, Nevada, New Mexico, Utah, Wyoming and western South Dakota (the middle and southern Rockies). For reasons explained earlier, even though portions of British Columbia and Alaska are clearly boreal, and therefore more closely matching the northern boreal region in character, we have included the entire commercial timberland of theses areas in this region.

The western North American forest region includes the coastal temperate rain forests as well as the dry interior pine savannahs. The coastal forest types cover a smaller fraction of this forest zone than the savannahs but they are far more productive and account for approximately one half of the forest industry in this forest zone. Both forest types are dominated by softwood species. Primary coastal species include western and mountain hemlock (*Tsuga* spp.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), and various true firs (Abies spp.) and western red cedar (*Thuja plicata* Donn). The interior forests are characterised by lodgepole pine (*Pinus contorta* Dougl.) and ponderosa pine (*Pinus ponderosa* Laws.) The main hardwood species group is Aspen/Poplar (*Populus* spp.).

3.3.2 Major Forest Types

This region is divided into the western coastal subregion and the interior mountain subregion. In the northern portion of the coastal subregion the northern coastal area includes the Sitka spruce- western hemlock forests, the Douglas-fir forests, and the higher-elevation mixed-conifers includes true firs and mountain hemlock. In the south the forest is dominated by Douglas-fir, white fir, ponderosa and redwood forests. Several oak species make up the majority of the hardwood component.

The combination of seasonal climate controls, proximity to the Pacific Ocean, and physiographic features provide the Pacific Northwest with remarkable climatic variation. The ocean is a major influence in the climate, serving as a source of moisture and as a control of temperature extremes. Mountains ranges such as the Cascades and Rockies change the forest type dramatically. They also have a major influence on the harvesting and silvicultural techniques applied. Wind is also another major climatic influence on forests. Often industrial forest management planning is thrown into chaos as a result of the wind damage where clear-cut timber harvesting occurs. In terms of productivity, this region is one of the most productive in North America. Tree growth can be as much as 10-20m3/ha/yr.

The interior subregion includes the interior portion of British Columbia and the inter-mountain area of the United States. The northern portion is composed of ponderosa pine, Douglas-fir, grand fir, Engelmann spruce, lodgepole pine and ponderosa pine. In the south, ponderosa pine forest accounts for 40% of the total area of commercial forests. In terms of forest types, the pinyon-juniper forest, is the most important. In the hardwood forests of this subregion only the aspen is considered commercially important.

Typically all forest areas in the region are mountainous and the mountains have a major influence on the areas' climate. The topography also influences precipitation which is highly variable and tends to increase with elevation.

3.3.3 Past and Present Forest Use

In this western portion of this region the forest use started on areas accessible to water and moved progressively inland and onto more extreme topography as logging equipment improved and demand increased. Historically, clearcutting, followed by burning, has been the primary harvesting strategy. Through much of the 1800s harvesting of trees on the west side was confined to areas that were within skidding distance of mills (or water). However, this was not a severe limiting factor given the abundance of water courses. In the 1880s logging railroads were developed, which allowed logging operations to move away from immediate vicinity of water to any area suitable to a railway grade. Power skidding was introduced in the 1890s with the advent of the steam donkey. The use of logging trucks and tractors became widespread in the 1930s. This was followed by the introduction of cable skidding, rubber-tired skidders, mechanical shears, and balloon and helicopter logging.

Over the last century, the forests have been progressively clear-cut and the second-growth forest is now a major portion of the wood supply. This is because the remaining old-growth forests have been largely set aside to meet other social objectives. For the forest on the western portion, 17% of the old-growth Douglas-fir that existed in 1800s remained in 1988 in Washington and Oregon. Roughly 45% of this remaining old-growth, found largely on public land, is already protected (Barrett 1995). In British Columbia, there are already projections of up to 30% to 50% reduction in harvest levels in some areas.

One of the most significant concern of the region is forest fragmentation. The landscape has become increasingly fragmented as relatively small clearcuts are continuing to reduced the size of the remaining unharvested blocks. Forest fragmentation can have significantly negative environmental effects. Checkerboard ownership patterns have also contributed to fragmentation, as there is little co-ordination in the past among mixed groups of owners across the landscape.

In the Rocky Mountains, the forest was initially impacted by agricultural settlement and timber harvesting . With agricultural development came heavy use of open forest types for grazing of cattle and sheep. Today the numbers of animals have been reduced to a more sustainable level and the recently cutover forest areas offer an important source for animal forage until tree development reduces understory growth. Logging was the other mainstay of the economy in this area starting in the middle of the 19th century. White pine was the commercial crop for decades and eventually the species was extensively harvested by clearcutting. Today there seems to be three main limiting factors to this traditional approach to development: the prevalence of fire, poor land productivity and difficulties of access due to topography.

In general making a shift to a sustainable economic development approach also has its challenges. First is the impact of protected area designation (such as roadless areas, wilderness and riparian areas) on timber harvesting. It becomes particularly controversial when the insect, disease and fire outbreaks on protected areas spreads to adjacent forests managed for other objectives such as for timber. Second is the concern with forest health. In some forests, mortality currently exceeds growth and salvage comprises most of the annual timber harvest. Economic selective harvesting (high-grading) and fire exclusion policies have encouraged the development of overly dense stands and have changed species composition and structure of much of the forests. Many of the most damaging insect and disease problems affect these tree species, so there seems to be an obvious relationship between past management practises and policies and current forest health problems.

3.3.4 Area, Volume and Harvest Levels

Since this is a very complex region, we have broken the discussion of the volume and projected harvest levels into the following administrative units: Oregon and Washington, California, Alaska, Idaho and Montana, middle and southern Rockies and British Columbia. The area, volume and harvest levels are summarised in Table 3.3.

TABLE 3.3 OVERVIEW OF FOREST SIZE AND HARVEST LEVEL IN THE WESTERN NORTH AMERICA REGION

	Total Land Area (000 000 ha)	Productive Forest Land (000 000 ha)[1]	Proportion Forest Land Privately Owned in %	Total Growing Stock (000 000 000 m3)	Allowable Cut (000 000 m3)	Actual Harvest (000 000 m3/yr) in 1991	Actual Harvest (000 000 m3/yr) in 1992
Oregon and Washington	42.00	15.3	43	3.53	-	103.8	67.8
California	40.40	6.6	46	1.42	-	34.7	
Alaska	147.80	6.10	39	1.00	-	8.3	
Idaho and Montana	59.00	12.30	27	1.73	-	19.8	
middle and southern Rockies	163.50	11.60	32	1.28	-	6.2	
British Columbia	94.80	49.00	5	9.94	75.00	74.7	75.0

Sources: Barrett 1995, BCMOF 1995, ECE/FAO 1995, CCFM 1994, Powell 1994, Runyon 1991, Waddell et al. 1989.

The type of forestland ownership is significantly different between the US and Canadian portions of the region. Future timber supply for paper production will be affected by a number of issues related to land ownership. First, as demonstrated in the description below on public lands, management objectives are now more diverse, which will likely decrease wood supply for paper. Second, it is unlikely that remaining public land in the region will be privatised. Third, a recent survey shows that private land owners expect their timber supplies to decrease by 1-12 percent because of new regulations restricting harvesting activity (Barrett 1995). The statistics compiled for each of the areas described below seems to support the thesis that these issues are of central importance.

Washington and Oregon

Not all productive forest land is available for harvesting. The latest estimate of productive forest land in the National Forest is that 4.5 million ha is available for timber management of which 1.1 million ha will be heavily restricted by the zoning of the area for such things as wildlife and fish, scenic areas and viewsheds and recreation. This may be optimistic since some environmental groups are calling for a total ban on timber harvesting on the National Forests (Apsey and Reed 1995). Private commercial land is 6.7 million ha and harvest

[1] Productive forest land is defined as any land capable of producing a merchantable forest within a reasonable time period (Runyon 1991). Therefore the definition is different from the US where it is defined as any forest with growth in excess of 1.4 m3/ha/yr.

level have risen significantly to compensate for the loss of timber volume from the USDA Forest Service controlled lands. The projected change in timber harvest levels is dramatic for the US federal land portion of the western region. For example, the projected softwood harvest level for the year 2010 has been reduced from 125 million m3 to 76 million m3 (Apsey and Reed 1995).

There will be an impact on state and private lands as well as a result of the proliferation of government regulations. Currently there is acceleration of harvesting on the private lands which is seen to be sustainable into the next century. This could change with the rapid increase in the number of private land regulations which will restrict timber harvesting (Greene and Williams 1994). Most commercial forests are found in the western portion of the area where 60 percent of the land is capable of growing in excess of 8 m3/ha/yr.

Alaska

On public land the majority of the commercial timberlands are in the coastal regions. The National Parks Service has management responsibilities for areas ranging in size from 50 ha to 5.2 million ha and the main management objective now is to maintain biological diversity. On the areas administered by the USDA Forest Service (9.1 million ha) 34% has now been designated as wilderness area by law. Forest and landscape diversity are preserved at many scales of resolution, from single and multiple watersheds to entire islands. This means that the amount of timber available in the future from the federal lands is continuing to be reduced to meet objectives other than wood production.

The majority of the private land holdings in Alaska (approximately 3.3 million ha) is owned by natives but the amount of this land considered commercial timberland is unknown. Land management objectives vary from subsistence use to large-scale natural resource development. One estimate is that 2.5 million ha could be considered private timberland (Waddell et al. 1989).

Idaho and Montana

Of the 17.4 million ha of forest land (any land with greater than 10% cover) approximately 12.3 million ha is classified as commercial forest land. Large tracts of federal forestland are managed as wilderness, and additional roadless areas are being studied for possible wilderness classification (Barrett 1995).

Growth exceeds cutting for the region in terms of total growing stock. For example, net growth amounted to 36 million m3 in 1987, an amount considerably greater than the removal figure of 18.5 million m3 (Waddell 1989).

However, this can be a very deceptive figure in assessing the sustainability of the wood supply. For example, mortality accounted for the loss of another 50% of the growth and not all that is growing will ever be economically accessible. This could mean that the harvest level could be too high even in this region even under traditional timber management.

Fire has shaped the character of forest ecosystems in the northern Rockies. Prescribed fire is now being more frequently used in the management of forests in this area. This will become increasingly important where management objectives focus on maintaining health and functions of the ecosystems (Barrett 1995). Given the risk of losses associated with the use of fire, sustainable timber harvest levels projections should incorporate a risk factor to allow for such losses under ecosystem management.

Middle and southern Rockies

The forest of this area is characterised by mature or overmature (at least from a timber management point of view), slow growing, conifer stands. Tree growth rates range from 1.4 to 7.0 m3/ha/yr but the majority is in the lower growth rate classes. The timber rotation age can range anywhere from 80 to 160 years depending upon site and species. This indicates in gross terms that the timber productivity is lower, particularly as compared to other portion of the region, with the exception of Alaska.

The old growth represents a greater portion of timber than it does in other regions. The old growth that is harvested is largely for sawtimber purposes, since limited supplies of water restricts the use of material for pulp (Barrett 1995).

Forest resources other than wood often determine management objectives. These resources include: water yield, recreation opportunities, livestock grazing and wildlife habitat. Therefore the appropriateness of traditional sustained yield timber management is now being reassessed. One important trend, which is consistent with the shift to ecosystem management is an emphasis on landscape management, where the emphasis is on preventing forest fragmentation.

California

Historically, California has ranked among the first three states in terms of national timber production, producing 18.4 million m3[2] in 1976 (Barrett 1995).

[2] 1 board foot = 0.00348 m3, 1 cubic foot = 0.0283 m3

In 1991 the estimated net volume harvested was 29.5 million m3 (Powell et al 1994). In 1993 the estimated harvest from timberland was 9.0 m3 (Barrett 1995) and 76% of that came from private land. The harvest from federal land in 1993 dropped by 66% due to withdrawal of forest lands for other purposes and reduction in harvest due to concern with the spotted owl.

The more productive timber lands are private lands at average rates of 14.3 m3/ha/yr versus public lands where the rate is 3.8 m3/ha/yr. The average growth rate on all lands is 5.9 m3/ha/yr. Rotations of 40-60 years are common using economic criteria on private lands. On public land the rotation is normally 50-80 years in unthinned stands and 100-120 in thinned stands on public lands. Longer rotation of up to 150 years are being considered for some species as a result of efforts to implement ecosystem management.

The changes in silvicultural practices in some Californian forest types began with the *unit area control method*, which is essentially a management by small homogenous groups or condition classes (Barrett 1995). This formed the basis for the current approaches to group selection.

To respond to the changes demanded by society, distinctive silvicultural approaches have resulted from a consideration of such issues as taxes, forest practise legislation, local county ordinances and public policy. This is in addition to the more typical silvicultural determining factors such as soil and species characteristics (Barrett 1995). This makes predicting future timber supply even more challenging since decisionmakers must not only deal with biological uncertainty and difficulties in measurement but also social and economic uncertainties as well.

British Columbia

In British Columbia the current committed level of harvest is 71 million m3 even though actual harvest was much higher in the early 1990s (100 million m3). The recently introduced Forest Practises Code and other initiatives are expected to reduced the AAC by anywhere from 10% conservatively to 20% (Barclay 1994) resulting in the AAC will dropping from 71 million m3 to a range of 67.5 to 60 million m3. In addition to the impacts of the Forest Practises Code there is an impact of other policy initiatives, particularly from land use planning. There are currently three major initiatives: Commission on Resources and Environment, the Protected Area Strategy and Land and Resource Management Planning. The amount of productive forest land withdrawn as a result of these initiatives could be 6% or more.

The harvest level could be reduced even further if the harvesting/silvicultural system for Clayoquot Sound is promoted to other forest areas. It is expected that the harvest level will be reduced by at least 50% from the amount previously allocated for the region. If this type of cut reduction is applied to all of British Columbia then the reduction in AAC would be from 75 million m3 to 37.5 million m3 (Lush 1995).

In the short term the private forest lands on the coast will provide more timber to make up for a portion of the shortfall. However, in the longer term, the current harvest levels on private land may not be sustainable as companies seek to meet the demand for wood material in their mills with their own private wood.

3.3.5 Sustained Timber Yield Management in the Western Region

Sustained timber yield management in the western region has been characterised by progressive clearcutting. The primary reasons for this approach are technical, economic and biological in nature. Technically, timber harvesting in forests with the typically steep terrain requires the use of cable yarding systems which, with most cable systems, requires clearcutting. From an economic point of view it was necessary to have high volume removals since the cost of access roads are very high in steep terrain areas. Finally, from a biological point of view, wind blowdown, insect outbreaks and tree disease damage were best dealt with using the clearcutting method. In addition, the aim of many forest operations was to produce a different kind of forest crop-the even age single species forest. This meant, for example, that clearcutting, prescribed burning and other site treatments would prepare the soil to grow species such as Douglas- fir for future lumber markets. This seemed to be the most rational approach to managing forests for the future in the Post World War II era, where the primary concern was economic development.

3.3.6 Ecosystem Management in the Western Region

Clearcutting has become increasingly unpopular with the public, particularly as it relates to the harvest of old-growth habitats. In addition, intensive forest practises is also unpopular, since it is based upon principles of simplification and homogenisation of the forest resource at the tree, stand and landscape level in order to maximise short-term economic returns. Forest management approaches based on these principles, such as clearcutting and plantation silviculture are now subject to heavy criticism. To respond , public land managers are actively seeking alternative silvicultural systems in both the western and eastern portions of the region in order to adapt to broader societal objectives.

In the western portion of the region a current issue is the modification of traditional practices for second-growth stands to create at younger ages the structural features of old growth stands. Desirable features include large trees, snags, coarse woody debris on the ground and several canopy layers (Franklin 1992, Maser 1988). Some attempts to modify clearcutting plantation practises have included reserving some mature trees throughout the next rotation to provide structure, future snags, and coarse woody debris. The intensity of site preparation has been reduced to leave slash on the site. A variety of precommercial and commercial thinning regimes are also being tested in young plantations to stimulate the rapid development of more complex structure where it is desired. Other approaches, with landscape level implications, include lengthening rotations and slowing the rate of harvest (Barrett 1995). The overall interest is increasing in the use of uneven-aged management on the coastal species through either single-tree or group selection methods, to create fine-grained landscape pattern.

One of the forest management approaches receiving the most attention in this region has been called New Forestry (Hopwood 1991). The result of the traditional approach is defining management activity in terms products and amenities. But in the search for that efficiency, we ignored other values (Franklin 1989). The solutions generally proposed to solve this value problem was to move towards intensive management for different values in different areas. For example, some lands would be used exclusively used for commodity production and other land preserved completely from timber production. New Forestry takes a different view. It does not, in principle, see the protection of ecological values and timber production as incompatible. In essence the new approach is 'kinder and gentler' and thus is better in accommodating ecological values. The ecological values which needed to be considered included amount and structure of organic debris on land or water, wildlife habitat trees, litterfall, old growth forests, and biodiversity. Although there has been a long history of silvicultural and autecological research, the study of natural forests as ecosystems is a relatively recent development. Recent studies have shown that the natural forests are far more complex than we imagined in terms of their composition, function and structure (Franklin 1992).

With this expanded ecological knowledge and a broader set of objectives, it is necessary to create new forest management systems that better integrate the commodity and environmental objectives. In fact the importance of many of these ecological processes and organisms to long-term productivity of forest lands would make change in forest practice imperative, even without considering other objectives, such as maintenance of biological diversity for aesthetics or ethical reasons. The new approaches to forest management must incorporate the best current ecological science as well as providing feedback mechanisms so that new technical information can be continually incorporated.

In terms of practise, there is no intent to throw out clearcutting and plantation management. The idea is to enrich forestry by adding new knowledge and new techniques to the existing approaches. In addition, the new practises may resemble older traditional forest practices that for example maintain mixed-structure stands (Franklin 1992).

There are stand and forest level implications of new forestry. At the stand level new forestry requires managing young stands for diversity, maintaining coarse wood debris and harvesting systems which creates uneven aged stands (stands with more than three age classes per stand). At the landscape level new forestry requires the consideration of larger spatial scales and longer temporal scales in planning management activities. Decisions on the spatial scale of harvesting and the geographic distribution of management activities will vary dramatically with the characteristics of the landscape and the organism of interest.

In the eastern portion of this region fire suppression, selective harvesting systems and severe droughts have resulted in forest health problems over large areas. Fire suppression has had a homogenising effect on the landscape that has contributed to forest health problems. To address the problems with forest health efforts are being made to re-establish a greater component of seral species and to manage stand densities to reduce damage in the future. In addition, there is a trend towards fewer and smaller clearcuts and towards more partial cutting. This will increase harvest preparation and logging costs. Snag retention for wildlife and for future woody debris is increasingly a feature of silviculture prescriptions but it has safety and logging costs implications. The application of regeneration methods that include long-term retention of residual overstory is expected to alter growth and yield. The degree and method of slash disposal are changing due to greater knowledge of the importance of woody debris in nutrient cycling and the role of nutrients in insect and disease resistance.

Greater appreciation of the importance of understory vegetation in nutrient cycling and the overall functioning of the forest ecosystem is causing changes in how this vegetation is managed. Plants that were considered to be merely competition for trees are now recognized as essential components of the forest. And finally, concern about the impact on some wildlife species of forest fragmentation is changing the way which harvest units are distributed across the landscape.

At the applied level the most recent comprehensive application of ecosystem management is in the Clayoquot Sound region of British Columbia (See Box 4).

Here the silvicultural system will change dramatically. The alternative systems, known as the *variable retention silvicultural system*, is a combination of the traditional silvicultural systems of seed tree, shelterwood, selection, clear-cut with reserves and other reserve systems. Its general aim is to retain trees and patches of forest in a managed forest to protect a variety of values and ecosystem components. The retained trees and forest patches create forest characteristics similar to patterns and remnant structures left after natural disturbances (SPSFP 1995).

To implement the variable retention silvicultural system requires the use of different tree harvesting systems. Generally the shift is towards skyline yarding since it minimises soil disturbance, damage to residual trees and still maximises yarding productivity. The transportation systems will also change, with an emphasis on the reduction of road densities, narrower roads, road deactivation after harvesting, revegetation of all disturbed areas associated with roads, and the increased use of dryland sorting to reduce damage to near shore marine waters.

In summary, prescribed burning, new forestry and the variable retention silvicultural system are offering both the justification and tools for change in forest management. While still working in the experimental stages, at least in many instances, there is a clear trend toward the broader application of ecosystem management in the western region.

Box 4. Western North America Region - Clayoquot Sound, British Columbia

Clayoquot Sound, on Vancouver Island, British Columbia, represents a land area of about 260 000 ha of forested land. Of the 160 000 ha of commercially productive land 30 000 ha has already been logged, 39 000 is in protected areas and the remaining area of 91 000 ha is predominantly old-growth forests.

Environmentalists were concerned that the western coastal temperate rainforest was quickly disappearing and the First Nation's perspective was missing in land and resource planning. The provincial government created a Scientific Panel to make recommendations on how to incorporate a full range of forest values, including those of the First Nations.

The cornerstone of the Panel's recommendations are principles for ecosystem management. This has implications in terms of planning, roads, timber harvesting systems, and silviculture.

Under the recommendations, the planning system will change in a number of significant ways: 1. The basis of forest planning will be area based constraints, not volume based. This means that at different planning scales there is a maximum area that can be harvested at any point in time. At the watershed level it will be 1% per year. Previously a theoretical sustained volume of harvest determined the area cut. 2. The planning will be controlled much more at the local level. 3. First Nations people will be included and traditional and scientific knowledge will be integrated. 4. The planning process will emphasize adaptive management and policy, which allows the incorporation of new information and experience as they develop. Planning will now be more complex and preliminary estimates are that planning costs will increase by more than 80% (Thibodeau, 1994).

In order to implement ecosystem management, more roads will have to be constructed in the next few harvest periods in order to meet the spatial constraints imposed at different planning scales. Studies in other areas of British Columbia and applicable here estimate increase in road development is 40% in the first two decades and the cost increases attributable to roads more than 70% (Nelson *et al* 1993; Nelson 1993). Keeping roads active for logging activities will also increase road maintenance costs by more than 30% (Nelson *et al* 1993).

The method used to yard trees will also change. It has been recommended that a switch be made to a skyline yarding method (lifting trees from stump to roadside) from high lead yarding systems in the mainly steep terrain. The increase in cost could be more than 20% (Thibodeau 1994), except in those areas where the volume removed exceeds 350 m3/ha. In this case there is no significant increase in costs (SPSFP 1995:115). The harvest volume could be reduce by anywhere from 1-41% but harvest reduction (Daigle as quoted in SPSFP 1995) in three other area was between 32 and 54% (Nelson 1993a; Nelson 1993b; Nelson and Shannon 1994;Thibodeau 1994).

The variable retention silvicultural system emphasizes the retention of trees and patches of forest in a managed forests to protect a variety of values and ecosystem components. The retained trees and forest patches create forest characteristics similar to patterns and remnant structures left after natural disturbances. The impact of the new silvicultural system on costs is estimated to be to negligible (Thibodeau 1994).

The total wood cost implications ranges could increase by 8% (Nelson *et al* 1993) to 25% (Thibodeau 1994).

3.4 Southern US Temperate Forest Region

3.4.1 Geographic Location

The southern forest zone is identical to the southern administrative zone that has been delineated by the United States Department of Agriculture (USDA) Forest Service. This region is essentially the southeast and south central United States, extending from Florida to Texas. The northern boundary of the region includes the states of Oklahoma, Arkansas, Kentucky, and Virginia.

3.4.2. Major Forest Types

There are three major forest types in the south. Pine forests form the backbone of the South's large and thriving forest products industry, even though they are not the largest forest type by area covered. The southern bottomland hardwood forest type occurs along all major and minor streamcourses, swamps, and floodplains in the south Atlantic and Gulf coastal area, extending upstream along the Mississippi River to southern Illinois and Indiana (which is in the eastern temperate forest zone). The third major forest type is the southern Appalachian hardwood forest, which extends southwards through the eastern half of Kentucky and Tennessee and the western parts of Virginia and the Carolinas into northern Alabama and Georgia.

Loblolly-shortleaf pine forests cover 47.0 million acres throughout the region. The other major pine forest type is a mixture of longleaf pine (*Pinus palustris* Mill.) and slash pine (*Pinus elliottii* Engelm. var. *elliottii*) which covers 14.1 million acres. This forest predominates in Florida and Georgia and is also common in states bordering the Atlantic and Gulf Coasts.

Pure natural stands of loblolly pine (*Pinus taeda* L.) are generally found on sites with relatively abundant moisture. Mixed forests of loblolly pine and shortleaf pine (*Pinus echinata* Mill.) are widespread in Texas, Louisiana, and southern Arkansas. Loblolly pine also mixes with a wide variety of hardwoods on wetter and drier sites throughout its range. On wet sites, typical associates include sweetgum (*Liquidambar styraciflua* L.) and tupelo (*Nyssa* spp) as well as a number of oak (*Quercus* spp) and ash (*Fraxinus* spp) species. On drier sites, oaks, hickories (*Carya* spp), and persimmon (*Diospyros virginiana* L.) are the most frequent hardwood associates. Longleaf pine may form pure natural stands or associate with oak and other pines on drier, sandy sites.

The major mixedwood forest type features oak and pine species, with numerous other species present in lower proportions. Many of these stands emerged following selective harvesting of pure natural pine stands (USDA, 1990). The area of this cover type is reported at 25.8 million acres.

Hardwoods cover a much larger area than the pine and mixedwood forest types combined; oak-hickory forests account for 74.5 million acres, oak-gum-cypress inhabits 27.5 million acres and mixtures of elm-ash-cottonwood and maple-beech-birch cover a combined 3.7 million acres (Powell et al., 1994). Oak-gum-cypress and elm-ash-cottonwood stands comprise the bottomland forest type whereas the oak-hickory and maple-beech-birch stands to belong to the southern Appalachian group.

The southern bottomland hardwood sites are very productive, yielding high quality sawtimber and pulpwood. The most important species are eastern cottonwood (*Populus deltoides* Bartr. var. *deltoides*), sweetgum, American elm (*Ulmus americana* L.), and black ash (*Fraxinus nigra* Marsh.). Baldcypress (*Taxodium distichum* (L.) Rich.) reaches its best development in the humidity of the coastal locations in the south. Other associates include red maple (*Acer rubrum* L.) and silver maple (*Acer saccharinum* L.), various oak species, and black willow (*Salix nigra* Marsh.).

These forests have an extremely high diversity of species, with over 75 tree species alone (Hodges, 1995). Forty of these species have commercial value, however many of the most valuable species have been greatly reduced in abundance due to high-grading practices. High-grading has also reduced the abundance of large stems and sound, high-quality stems.

3.4.3 Past and Present Forest Use

Minor amounts of timber harvesting are recorded in the southern US before the Civil War (1861-65) but it was not until the subsequent development of a large-scale railway system that intensive commercial forest harvesting began. At this time, the Coastal Plains area was covered by pine forests and these were harvested from 1880 to 1920 to provide lumber for housing markets in the Northeast and midwestern US. Clearcutting began in the bottomland hardwoods at the turn of the century (Hodges, 1995). Much of the land that was cut was converted to agriculture and pasture. These conversions, and the extensive and largely uncontrolled fires that burned during this time, led to substantial reductions in forest area. The forest that did return (the South's second forest) supported the expansion of the pulp and paper industry that began in the 1930's and has continued until the present day.

Until the 1920s, the area under agriculture and pasture increased steadily. This created widespread concern over the lack of regeneration, leading to the institution of a range of programs aimed at countering the situation, most notably a fire prevention and control program. With the onset of the Depression, farmland was abandoned and returned back to forest, which added large areas to the forest estate through until the 1950s. These stands collectively became known as the South's third forest. During the mid-1980s, the third forest supplied 2/3 of the US pulpwood harvest, 1/2 of US veneer production, 40% of the hardwood lumber and 1/3 of the softwood lumber manufactured in the US.

In the early 1950s, the land use tide reversed and forest land began to move back into agriculture again. The productive and relatively flat bottomland sites were especially coveted and roughly 1/4 of the area has been converted to farmland since 1952. Of these sites, roughly 91% of this forest type is privately owned; non-industrial interests own 66% and the forest industry owns 25%. The remainder belongs to state and federal governments.

The other kind of forest, the result of from artificial regeneration on second forest cutovers, and this is now the main source of industrial softwood fibre. On some of the forest types in this zone, revenue from wildlife leases exceeds revenue from timber production in some areas. This increases the appeal to small NIPF owners of reducing forest harvesting activity.

Robertson (1988) reported that current employment levels will not be sustained after 1990, with a 25% reduction in the forest industry (woods and manufacturing) employment predicted by 2030. Much of this is due to the replacement of employees with technology; without industrial expansion there is no countervailing trend. Finally, some possible future supply reductions can be expected to have a wide range of implications for wildlife, recreation users, and the quality of the ecosystem.

3.4.4 Area, Volume, and Projected Harvest Levels

As Table 3.4 shows, roughly 40% of the land area in the US South, or 208.8 million acres, is classed as non-reserved forest land. Land in all but the lowest productivity class is designated as timberland; this area equals 199.3 million acres. Approximately 90% of the forest area is privately owned; 39 million acres (19% of total area) is industrially owned and 148.5 million acres (71%) is under other private ownership. In 1978, there were reported to be 3.5 million owners of non-industrial private forest (NIPF) land. Ninety-two percent of these owners own fewer than 100 acres but the remaining 8 percent control 73 percent of NIPF land. This leads to a diverse set of land use objectives and offers a wide range of possible futures.

Actual harvest data consists of roundwood harvested plus other removals.

TABLE 3.4 OVERVIEW OF FOREST SIZE AND HARVEST LEVEL IN THE SOUTHERN US TEMPERATE FOREST REGION

Sub-region	Total Land Area (million ha)	Productive Forest Land Area (million ha)	% Private Owned	Total Growing Stock (million m3)	AAC (000 m3/year)	Actual Harvest (million m3/year)
South-east	59.68	34.86	88.6	3420.68	na	127.37
South-central	156.72	49.68	90.7	3671.13	na	144.68
South total	216.40	84.53	89.8	7091.81	na	272.04

(Source: Powell et al., 1994)

Much of the forest area is very productive. Aside from the Pacific Northwest USFS sub-region (which is only part of the western temperate zone described above), the US South contains the highest proportion of timberland that falls into the most productive forest class in North America.

The softwood growing stock is primarily loblolly and shortleaf pine, long leaf and slash pine, and other pines. White and red oak are the most common species groups, followed by sweet gum and yellow poplar.

Hardwood and softwood growing stock volumes have both increased by almost 60% since 1952. The bulk of the increase is in the south-central sub-region, where growing stock doubled during this period. However, during the past five years, softwood and hardwood volumes have followed divergent paths. Softwood volume declined by roughly 2% since 1987, largely due to land withdrawals and declining pine growth rates. In contrast, hardwood volume increased by 9.4% during the last five years. The growing stock of bottomland forest species has increased by 8% since the last inventory period; current growth outpaces removals by a ratio of 1.4:1.0. However, many stands are badly understocked and the volume of high-quality material has decreased due to high-grading.

The decline in the growth rates of pine has been in progress since the mid-1980s and is very troubling for the region. Net growth has been reduced by roughly 5 % in the last ten years ago. Robertson (1988) outlined four reasons for this fall-off:

1. Inadequate regeneration on lands owned by non-industrial private landowners. Many landowners accept the natural regeneration, which is either of mixed hardwoods and softwoods or which is pure hardwood.
2. Pine mortality has increased from 9% to 15% of the gross annual growth from 1980 to 1990; much of this is attributed to pine bark beetles.
3. The radial growth of pine throughout much of Georgia, Virginia, and the Carolinas has fallen by 20 to 30% over the past decade. The reasons for this drop-off are unknown; speculation ranges from acid rain and adverse weather conditions to hardwood competition and a reduction in nutrients left from previous agricultural use. To date, there have been no well-accepted explanations offered.
4. The area of timberland is declining as it is being converted to other uses, primarily agriculture and urban expansion.. Between the early 1960s and 1988, the area of forest declined from 197 million acres to 182 million acres. Between 1980 and 1989, the area of forestland has shrunk by 3 million acres or 1.5%. Much of the lost area has come from pine forests.

There is no AAC calculated for this region, in part because so much of the forest land is privately owned. However, it is possible to estimate how the current harvest levels compare to the equivalent of the AAC by looking at growth versus removals. For softwoods, the volume of timber removed is virtually equal to the net growth volume. In 1986, the ratio of these figures was 1.02 (USDA, 1990) and it has declined to 0.88 in 1991 (Powell et al., 1994). In contrast, hardwood growth exceeds harvesting by a significant amount. Although these data are for single points in time and do not form a trend, they give the impression that the 1991 softwood harvest rate was likely at or above the AAC equivalent. With the unexplained reduction in growth, the already intensive use of pine plantations on industrial and large non-industrial land blocks, and the loss of forests; and to other uses, it is unlikely that the sustainable softwood harvest level can be increased in the next decade or so.

These prospects imply that timber prices will increase and that industrial capacity will be under pressure. Robertson (1988) cited estimates that softwood sawtimber prices are forecast to rise 3.1% annually from 1984 to 2000. Softwood pulpwood prices are expected to rise at a lower rate until about 1990 and then rise more rapidly. On the other hand, hardwood stumpage prices are forecast to decline during this period as hardwood growing stock increases.

Ninety percent of the harvest volume was in the form of roundwood products with the remainder estimated from land clearing and precommercial thinning. The latter volume was likely the scattered softwoods in hardwood forest land converted to other uses; usually softwood timber from cleared land is felled and sold as a timber product. An additional 10% was harvested and left in the bush as logging residue.

Softwoods comprise 64% of the roundwood harvested. This harvest figure represent substantial increases over the decade for which most recent comparison available, reflecting the expansion of the industry in the south. Total removals have increased by 9% since 1986 and by 34% since 1976. Since 1976, the use of hardwoods has grown more rapidly than the use of softwoods, reflecting the greater availability and lower price of the former.

Private landowners, as well as public landowners, face increasing regulatory constraints ranging from provisions to protect water quality to restrictions on chemical use and clearcutting (Guldin, 1990).

3.4.5 Sustained Yield Timber Management in the Southern Region

Sustained yield timber management is exemplified by pine plantations, which are increasingly replacing natural pine stands, and the use of various partial cutting techniques in the hardwoods. Some of the mixed hardwood stands are being converted to pine, especially on sites where the original stands were pure pine. The following overview of sustained yield timber management was chiefly derived from Walker (1995), Hodges (1995), and Smith (1995).

The typical pine plantation regime calls for intensive site preparation (often either shearing all vegetation, then windrowing and burning it or disking and bedding sites), planting improved stock or seeding, followed by one or applications of herbicide to eliminate grass or hardwood competition. All pine species are very intolerant and will not survive overtopping. Seeded stands are often precommercially thinned to control density. Plantations are normally of a single species. Mixed stands of longleaf and slash pines are difficult to artificially reproduce due to different early growth characteristics but loblolly pine is compatible with shortleaf pine in all stages of development.

Natural stands of loblolly-shortleaf pine are often thinned starting at ages 10-16 years. Pulpwood can be produced in 20 years and small sawlogs at age 40 on average sites. Under intensive plantation management, quality sawlogs can be produced within 30 years. Natural shortleaf pine is rarely maintained longer than 70 years since net growth rates fall rapidly beyond this age. Loblolly pine can be maintained until 80 to 100 years.

Fire is an integral part of the pine ecosystem, especially for slash and longleaf pines which prefer drier sites. Fire return times may be as short as 1-3 years in mature pine forests; these fires eliminate brush and hardwoods, maintaining grass. While such fires may eliminate young pines as well, the frequent return of fire favours the continuance of conifer cover. When fire is excluded, pine stands gradually convert to hardwood stands, typically oak and hickory mixtures. Prescribed burning is widely practised for hazard reduction, preparing seedbeds for natural reproduction, disease control, and improving quail and turkey habitat, and to improve grazing, in addition to its use in hardwood control. Longleaf pine is particularly dependent upon fire; after germination, it remains as a tuft of 40-50 cm long needles (the so-called grass stage) for up to ten years before it grows explosively. During the grass stage, it is fire tolerant and requires fire to eliminate competition. It is also susceptible to browsing pressure, since its roots are rich in carbohydrates stored to fuel its explosive growth. Loblolly-shortleaf pine are often found on wetter sites. There is enough moisture on these sites to support both a hardwood understorey and the pine canopy and so fire is less of a necessity. However, where these pines are over-topped by hardwoods, the removal of the hardwoods is essential for the maintenance of the pine component.

While shelterwood and selection methods are difficult to apply successfully in the loblolly-shortleaf forest, the seed tree method is widely used. Seed trees may be removed two years after the initial cut of maintained as fire insurance and taken out in the first thinning.

Longleaf pine forests support populations of white-tailed deer, wild turkey, and bobwhite quail. These species benefit from repeated fire and find their best habitat where pine stands are at somewhat less than full stocking and are intermixed with swamps and other drainages. Mature longleaf pine stands are also home to the endangered red-cockaded woodpecker. US courts have ordered the Forest Service to improve habitat for this species and on private land it is a federal offence to harass or harm the birds in any way.

Frampton (1988) reported that intensive plantation management involves increased use of herbicides, increased stocking, shorter rotations, and more intensive site preparation. These generally have adverse impacts on the ecosystem and on wildlife populations. Large scale use of herbicides on clearcuts or hardwood forests makes these areas unusable by wildlife for 2 or more years. Increased timber production from private land will mean that the only areas of natural mature and old-growth stands will be on public lands, increasing the pressure on these lands to produce a diverse mix of benefits.

The bottomland forests are governed by water levels and flooding; species have different levels of susceptibility to each factor. A second factor of importance is siltation; in some sites rapid siltation may quickly change the character of the site and cause a shift in species composition. Black willow and cottonwood tend to be pioneer species, exhibit rapid growth and high tolerance to flooding. These species are typically managed on an even-aged basis at rotations ranging from 30-35 years for sawtimber; cottonwood plantations yield pulpwood by 12 years and sawtimber after 20 years. Growth is enhanced by thinnings, which can start as early as 15 to 20 in natural stands and 8 years in plantations (Walker and Watterston, 1972).

Cottonwood is the only southern hardwood which is planted (Walker and Watterston, 1972). Seedlings, wildings, and cuttings have all been used successfully as planting stock. Cuttings have proven to be especially appropriate for cottonwood, especially in moist but unsaturated ground. Intensive site preparation is required for best growth response; the creation of shallow trenches or strips by bulldozer is a common technique. Recommended planting spacing is 10 x 10 or 12 x 12; the latter density will produce merchantable trees at the time of first thinning. The species responds well to fertilisation. Cultivation is essential during the first year to control competition. The use of seed trees also works well with this species but the lack of tolerance restricts the use of partial harvesting as a means of reproducing itself.

Sweetgum forms fully-stocked, relatively pure stands on the coastal plains, although the species often occurs with other species in older stands. This species is often managed on a selection basis, relatively heavy cuts are made every 10 years. Light partial cuts encourage the development of more tolerant species.

Cypress-tupelo forests are often found on sites which hold water for most or all of the year. Bald cypress can be extremely long-lived however current practice is to cut both tupelo and baldcypress before they reach 100 years. Harvesting is most often carried out when sites have dried but now helicopter logging and the use of large mats to permit the entry of machinery allows greater flexibility.

Both species are shade intolerant and even-aged management systems are advocated. However, regeneration of these species is very difficult to achieve on a consistent basis, largely because germinated seedlings will not survive flooding during the first year or two. Usually there is some advance regeneration if the stand has been opened by mortality and this, plus regeneration from seed and sprouts can regenerate the stand. In theory, shelterwood can be used on these stands but there are many operational problems and so it is rarely tried.

Later successional stands have such wide mixtures of species that prevent detailed discussion here. The most valuable species include 6-8 species of oak, sweetgum, and yellow poplar. They grow on sites that are above water and only rarely flood for short time periods. Hodges (1995) reports that most of these stands are managed on an even-aged basis, with harvest ages determined by the vigour of the stand. In practice, this results in rotations of 20 to 80 years, depending on species, product, and site productivity. Uneven-aged practices can also be used but the most valuable species on these sites are intolerant to mid-tolerant. Thus, for operational ease, cost savings, and to regenerate a more valuable stand, natural regeneration is almost always used. Where regeneration may be difficult to obtain, group tree selection is often recommended. Walker and Watterston (1972) describe the use of planting or direct seeding to establish oak plantations. Oak species regenerate well as long as the sites are not flooded for extended periods; however seed production is prolific only every 6 to 8 years on average.

Bottomland hardwoods grow on some of the most productive sites in North America. A wide variety of other flora and fauna are also present, including rare species such as southern black bear, ringed sawback turtle, and swallowtailed kite. For many species, the clearcutting and group selection methods produce good habitat conditions.

The management approaches used in third major species group, the Appalachian hardwoods, has been described in chapter 6. The general approaches remain the same throughout the region, even though in the south, the mix of species tilts in favour of red and white oak and hickory and away from hard and soft maple, beech, basswood, and ash.

3.4.6 Ecosystem Management in the Southern Region

One of the greatest obstacles to the practice of ecosystem management in the south is the large number of small NIPF land owners. When so many owners have small parcels of land, it becomes difficult to ensure that landscape scale issues are adequately dealt with. There is also no guarantee that owner objectives may not change significantly, thus the amount of land managed in a particular way depends both on rates of land turnover and on the distribution of ownership objectives. On the other hand, the sheer number of owners probably guarantees that most stand types will be present at certain levels throughout the forest. Issues relating to the feasibility of undertaking ecosystem management will not be discussed further here; suffice it to say that successful implementation will depend on the willingness of neighbouring landowners to work co-operatively.

There are two distinct sets of disturbance regimes in the southern region - fire dominates the drier pinelands while water levels, flooding and silt deposition affects bottomland sites. (Ecosystem management in the Appalachian hardwoods was described in Chapter 6).

The fires in the pinelands tend to recur frequently and are rarely intense enough to harm large pine trees. However, in drought years, fire can destroy large areas of mature timber and create conditions for the development of new pine stands. Wind is another disturbance vector that can operate at a large scale, as recent storms such as Hurricane Andrew attest. Other types of disturbance, such as lightening and disease, tend to remove only individual trees or trees in small groups.

In bottomlands, abnormal levels of flooding will kill large areas of timber. Since species have different levels of resistance, the duration of flooding affects the distribution of mortality among species. Fire is rarely a factor but when it occurs during severe droughts, there is often widespread damage since the species have little or no resistance. Thus, fire every two or three centuries can have a substantial influence on species distribution and forest cover, especially in forests with longer lived species such as oak and cypress.

The lack of old forest in the south and the likelihood that managed stands will be harvested at young ages implies that one emphasis of ecosystem management should be to lengthen rotations on a substantial portion of the forest. Doing so would improve the aesthetic quality of the forest and provide much needed elements of diversity. An increased reliance on natural pine regeneration, instead of on plantations, is also likely to be part of ecosystem management. The extent to which this is feasible depends on industrial demand and owner objectives, however there appears to be a high potential for landowners to earn revenue from hunting leases and this may be sufficient to induce owners to maintain more natural and longer-lived stands. Wildlife habitat can be improved by breaking up extensive pine plantations with wetlands, untended areas, or even with mature pine or hardwood stands.

At the landscape level, management should attempt to balance the area moving out of pine into mixedwood and hardwood with areas burned and restored to conifer. The use of fire to control hardwoods is not always practical on small ownerships, especially when they are near communities. Natural pine stands in such circumstances are likely to develop a greater hardwood component.

In the bottomlands, the commercially valuable species that have been depleted due to high-grading should be encouraged to regenerate. Many of these species are mid-tolerant and can be favoured through shelterwood and group selection systems, as well as using techniques such as enrichment planting and girdling. This point, plus diversity considerations, argue that the current emphasis on even-aged management should be reduced, especially since many of the bottomland forest types (i.e. the hardwood and mixedwood stands) frequently occur as uneven-aged stands. There is little literature comparing the impacts of clearcutting with the impacts of flooding. One obvious difference will be the large amount of dead standing woody material left behind after flooding.

Man has directly modified the water regime of the larger rivers and streams in much of the south (and indirectly modified that regimes of smaller ones). this has far-reaching implications for the bottomland hardwoods, which are complex forests with varied successional pathways available. It is not clear in what manner the existing water regimes differ from natural ones; these relationships must be understood before it is possible to preserve the functioning of natural forest ecosystems. Forestry authorities will have to co-operate more with hydro and flood control engineers to understand the impacts of changes to water regimes and mitigate these changes when they are adverse.

Unfortunately, there is no cost information of adopting ecosystem management readily available in the literature for the US South.

3.5 The Nordic Region

3.5.1. Geographic Location

For this exercise, the Nordic region consists of Finland, Norway and Sweden. These three countries' forests cover 77%, 31% and 69%, respectively, of the total land area (see Table 3.7). Closed forest areas are less, amounting to 66%, *28%, and 60%, respectively (Kuusela, 1994).*

3.5.2. Major Forest Types

Most of the forest area in the Nordic countries is boreal. This means that there are few dominating tree species, and they include Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), birch (*B. pendula, B. pubescens*), and aspen (*Populus tremula*). The southern limit of the boreal forests corresponds roughly with the July 18°C isotherm, and the northern limit with the July 13°C isotherm (Kuusela, 1994). Under natural conditions, lightning fire dominates the disturbance regimes, with return intervals of 50 yr on dry sites to 200 + yr on wet sites. While the conifers can, over the long run, outgrow the broadleaves, upon disturbance the broadleaves have some competitive advantage in getting established.

3.5.3. Past and Present Forest Use

Kuusela (1990) described the forest history of the Nordic region as follows:

> "The forests of the region have been under heavy exploitation since the 16th century. Only those areas which were outside the floatways and the pioneer fringe were left in a virgin state. Since then logging has rapidly reduced the natural forests. Exploitative forestry gradually changed to the simultaneous growing and harvesting of wood. The bulk

> of the current forests have been treated to (sic) by partial cuttings and silvicultural thinnings while the new seedling stands have been tended."
>
> "The tree species composition is a heritage of the time of unmanaged exploitation of natural forests for fuel, household purposes, charcoal, tar and shifting cultivation: a heritage which has gradually been brought under silviculture and management, and protected from fires. Without this past, the share of spruce would now be greater and that of broadleaves smaller".

Timber production has been a driving force in Nordic forestry, especially in Sweden and Finland, for more than a century. A major consumer of timber in Sweden up to the beginning of the present century was ore smelting. Almost all of the forests, except for some in alpine and sub-alpine areas, are managed for timber with considerable intensity (e.g., plantation regeneration, fire suppression). Some 20-25% of the total harvest volumes come from thinnings, and the remainder from final fellings (clearfelling).

Non-timber forest products and functions in Nordic forests are substantial. Hultkrantz (1991) reported the following values for annual production in Swedish forests: (a) for berries, 500 million SEK; (b) for 22 million kg mushrooms, 550 million SEK; and (c) for game (meat), especially moose, 467 million SEK. The Nordic forests are also very important for recreation and tourism, and many other non-market values.

3.5.4. Area, Volume, and Projected Harvest Levels

For the amount of land covered by exploitable forest, the Nordic countries have the highest rates of timber harvest among boreal-forest countries (see Table 3.5). Net annual increments per hectare are over 3 m3 in Norway, and over 4 in Sweden and Finland. Both Norway and Finland project substantial increases in NAI, and Sweden in growing stock. Harvest-level projections for the next 50 years show Finland's holding relatively steady, and Norway's and Sweden's to rise modestly (i.e., for Norway to a 2040 level of 15.5 million m3, and for Sweden of 77 million m3 (Pajuoja, 1994).

TABLE 3.5 OVERVIEW OF FOREST SIZE AND HARVEST LEVEL IN THE NORDIC BOREAL FOREST REGION

State /Province	Total Land Area (000 ha)	Productive Forest Land Area (000 ha)	Proportion of Forest Land Privately Owned (%)	Total Growing Stock (000 000 m3)	AAC (000 m3/yr)	Actual Harvest (000 m3/yr)
Finland	na	19,511	na	1,790	na	54,976
Norway	na	6,638	na	630	na	13,528
Sweden	na	22,048	na	2,557	na	64,600
TOTAL		48,197		4,977		133,104

3.5.5 Sustained-Yield Timber Management

According to Kuusela (1994), the growing of even-aged stands is the only profitable way to produce wood in the Nordic countries' boreal forests. Pine is grown on poor to medium sites, and spruce and birch on better sites. Planting and artificial seeding account for some 70-80% of all regeneration today. Most stands have a single-species canopy (for economic reasons), although there is a tendency lately to let broadleaved species, mainly birch, have a small share of the total canopy. Prescribed rotations in the south are 80-120 yr for pine and 70-90 for spruce, and in the north 110-180 and 90-140, respectively.

Fries et al. (1995) have provided a helpful summary of the main timber-oriented silvicultural techniques used in Sweden on the principle three forest types. Their basic messages are as follows:

(a) Scots pine on dry and mesic sites

Fire is the predominant disturbance agent, with a mean return time ca. 50 yr. Some stands are evenaged (having become established following crown fires), but some stands are multiple cohort, with older cohorts surviving ground fires. Natural stands have high degrees of standing dead and coarse woody debris (CWD). Regeneration practices today consist of planting to assist seed-tree regeneration, and disc trenching of non-lichen sites, resulting in evenaged, single-species stands of pine.

(b) Norway spruce or deciduous stands on mesic sites

The fire return interval of this type is 100-200 yr. The fires are more intense than in the previous type because they are less frequent and fuel loads are higher. Regeneration following fire is often broadleaved species and pine, but the full range of species, including Norway spruce, is possible, depending on fire intensity and other factors. There is usually lots of dead standing material, but CWD on the forest floor is not too high in these stands because decomposition is faster. Regeneration following final felling consists of scarifying and planting to produce conifer-dominated stands. The result is a low deciduous proportion, and little dead standing and downed coarse woody debris.

(c) Long-continuity Norway spruce stands

The fire-return frequency is ca. 200 yr and more, and these stands often occur on wetter sites. The dynamics are gap-dominated, with single trees or small groups dying at any one time. Such stands normally have huge amounts of standing dead and CWD. Many species require this forest type. In the current management of long-continuity Norway spruce stands, a wide variety of systems is used, including clearfelling with planting, shelterwood, and selection. Clearfelling with planting replaces naturally all-aged stands with essentially evenaged-stands. Regeneration has often been difficult, with water tables rising and tree recolonization late. Ditching has been used to combat this to some extent.

3.5.6 Ecosystem Management

Forest management in each of the Nordic countries is moving toward ecosystem management. For example, through a broadly consultative process, the Finnish government recently developed forestry environmental guidelines (Department of Forest Policy, Ministry of Agriculture and Forestry 1994). The government is looking upon the guidelines essentially as a strategic national forest environment policy. The guidelines recognize that past forest management has been decidedly timber oriented, and that the time is right for change. The document stresses two approaches to the focus on forest ecosystems. One is the protection of forest ecosystems in parks and reserves. It was stated that current programs are strong, but require stronger 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.

Forest management in Sweden is changing in such a way that biodiversity conservation is a goal of equal importance with timber production (Laemas and Fries, 1995). 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 both to timber production goals and to 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 (Laemas 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. As introduced above in Section 2, the Swedish approaches to forest ecosystem management described below are separated into stand-level and forest-level specifications of silviculture and forest-management regimes.

Three recent publications describe various forms of ecosystem management at the stand level.

3.5.6.1 Modified Stand Management

Fries et al. (1995) offered the working hypothesis that a combination of reserves (protected areas) and modified management of the timber-producing forest is the best approach to conserve 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.

(a) Scots pine on dry and mesic sites

Modified management for conservation of biodiversity calls for leaving seed trees behind, plus other means to create and leave behind dead trees. Low thinnings would be stopped, and a variety of thinning regimes would be used. Clearcuts and neighbouring stands from which good timber had been picked out would be burned.

(b) Norway spruce or deciduous stands on mesic sites

Modified management for biodiversity conservation would include modified clearfelling, and subsequent regeneration of evenaged stands. Large trees of all species (aspen, birch, pine, spruce) would be left behind in final felling. Rotations on whole stands would be lengthened. Scarification using burngin is useful. Other practices include: increasing the proportion of deciduous trees in stands; using patch scarification; and fill-planting with large seedlings some several years after clearcutting.

(c) long-continuity Norway spruce stands

Modified management for biodiversity conservation would abandon clearcutting and favour selection felling first, and secondly shelterwood. If shelterwood, fallen shelter trees would not be harvested.

3.5.6.2 Ecolabelling Criteria

The Swedish Society for Nature Conservation and World Wide Fund for Nature Sweden (SSNC/WWF, 1995) have developed "Preliminary Criteria for Environmental Certification of Swedish Forestry". The main focus of the program is conservation of forest biodiversity. The organizations encourage forest owners to view the increased costs of changing their forest management as investments, not as operating costs. There are 21 criteria that are focused on forest practices on small private holdings, obliging the owner in the following ways:

1. No timber-management activities in some key habitats.

2. Creation of set-asides of more key habitats, where only biodiversity-restoring activities are allowed.

3. Some habitats must be managed for biodiversity conservation primarily (therefore, no tree planting).

4. A minimum of 5% of productive forest must be kept in deciduous-dominated stands (therefore, no conifer planting).

5. Special practices must be applied on grazing/hay lands.

6. No chemical pesticides can be used.

7. No increase in fertilizer use is permitted; no nutrient removals that will have long-term deleterious effects on soil productivity.

8. There are special limitations on new logging roads.

9. Leave dead standing and CWD, except if insect infestations require control.

10. Keep deciduous species at minimum 10% of standing volume; leave the deciduous trees behind during final felling.

11. Protection of especially valuable natural features.

12. Try to balance the age-class structure. Keep a minimum of 20% of the total forest area over the minimum legal cutting age.

13. Use selection or shelterwood fellings in moist coniferous stands.

14. No operations in special habitats like riparian zones. Leave a minimum 10 mature trees/ha, and an average 20 trees/ha, upon final felling.

15. Create no new ditches; stop ditch maintenance in low-productivity bogs.

16. Use special precautions when scarifying.

17. Burn cuts to a minimum 5% of area cut.

18. Regenerate with indigenous tree species; favour natural regeneration.

19. Create no new coniferous stands on open land.

20. Conserve historic cultural forest values.

21. Practice openness and co-operation with local people, especially aboriginal people, in forest management.

3.5.6.3 The ASIO Approach

Ruelcker 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 - catches fire Almost never
- S - catches fire Seldom (return interval roughly 200 yr)
- I - catches fire Infrequently (return interval roughly 100 yr)
- O - catches fire Often (return interval roughly 50 yr)

The Ruelcker et al. (1994) paper describes typical conditions in each class, and provides broad suggestions for the types of stand management regimes that should be applied once a site has been classified into the ASIO system. These suggestions are broadly consistent with those of Fries et al. (1995).

3.5.6.4 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 (Stora Skog, 1994a) 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".

Alongside sustained yield timber production, which the company claims to have practised for a long time, Stora Skog declares 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.

Stora Skog (1994a; 1994b; undated) calls its broad approach "ecological landscape planning". The landscape units for planning are 5-25 K ha, depending on the land ownership patterns. Landscape planning for Stora Skog: (a) excludes from normal management key biotopes and permanent old growth for endangered species; (b) increases connectivity of habitats to increase dispersal possibilities; (c) assures a continuing supply of ephemeral old growth and hardwood-dominated types; and (d) applies greater biodiversity-conserving care to application of timber-intensive techniques such as fertilization.

According to its statements, Stora Skog (1994a; 1994b; undated) believes that it can profitably harvest high-quality pine and spruce logs while at the same time increase its annual cut and conserve forest biodiversity. The company claims that the annual cut is now below increment, so the cut can be increased a little each year. It wants as even a year-to-year cut as possible. The company will leave trees and residual patches during final felling, and use prescribed burning more in scarification. Regarding regeneration, the company will choose species best suited to soil/site. The company plans to double the number of hardwood trees in the forest (but not by planting), mainly for biodiversity conservation reasons.

3.5.6.5 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 used 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.

3.6 Europe

3.6.1 Geographic Location

The boundaries of Europe tend to change depending on the preferences of the authors collecting the statistics and on the time when the information was collected (Apsey and Reed 1994, Kuusela 1994, Prins and Korotkov 1994, Kuusela 1993, Nilsson et al 1993).

For the purposes of this report the boundaries of Europe is considered to be those countries west of the Ural mountains to the Atlantic. This means, for example, that the former republics of the USSR, Belarus, Estonia, Latvia and Lithuania and the Ukraine are included; however, some republics of central Europe are not included since there forest land is relatively unimportant. The

Nordic countries, which are also part of Europe, have been described as a separate region. The southern boundary is the coastline of the Mediterranean Sea.

3.6.2 Major Forest Types

The European forests can be divided into three principal forest zones[3]:

- Boreal coniferous forest in the northern latitudes
- Broadleaved deciduous forest in the temperature zones
- Evergreen mixed forest in the Mediterranean zone.

Boreal Coniferous Forest

The principal climatic variables which determine the growth of trees in the boreal coniferous zone are the temperature and the length of growing season. The temperature of the warmest months ranges from + 10 to 15 °C and that of the coldest months from +2 to minus 3 °C. The length of the growing season varies from 30 to 120 days.

Boreal trees are adapted to a fire ecology and for the invasion of treeless sites. Under natural conditions, wild fires ignited by lightning are repeated, on the average, approximately once in 50 years on dry sandy and gravel sites. The time between fires on moist sites is 100 to 150 years.

Birch (*Betula sp.*), aspen (*Populus tremula*) and alder (*Alnus incana*) and also pine (*Pinus silvestris*) on dry sands and gravels are pioneer trees which invade burnt sites. Spruce (*Picea abies*) is the only climax tree in northern Europe. Fire maintains the rotation of pioneer and climax stands, the fertility of sites and the biodiversity of the forests.

The average range of potential annual yield of stem wood is approximately 2 to 5 m3/ha. It is 1 to 2 m3/ha on most barren sites and 6 to 8 m3/ha on the best sites in those parts of the boreal zone where closed forest is possible.

Broadleaved deciduous forest

Broadleaved deciduous forest is the natural vegetation on most of Europe between the latitudes of 40° N to 60° N and longitudes 10° W to 45° E. The growing conditions, which are, in part, a function of radiation, light and temperature, change as you move form the north to the south. In addition,

[3] Between the boreal coniferious and broadleaved deciduous forest zones there is a latitudinal ecotonal, and on the slopes of mountains an elevational ecotonal mixed forests.

these conditions are also a factor of maritime influences in the west and continental influences in the east.

The temperature of the warmest months ranges from +15 to 20 °C and that of the coldest months from +5 to -5 °C. The mean annual temperature is +10° C. Wind can play a significant role in the Atlantic part and even in the central areas of this forest type. In the western part of the zone, the climate is moist-temperate, microclimates inside the forest are shady, and beech (*Fagus silvatica*) is often a climax tree. In the eastern portion, the microclimates are less shady, even sunny on some sites. Consequently oak (*Quercus sp.*) is a characteristic tree, often accompanied by pine (*Pinus sp.*). Under natural conditions, broadleaved trees predominate but pines are a common tree on sandy outwashes, possibly because of repeated wildfires.

The potential annual yield is at least 5 to 6 m3/ha. On the best sites it is 10 to 15 m3/ha. Yield is greatest in the maritime part where precipitation is greatest and lowest in the southeast where potential evaporation exceeds precipitation.

Evergreen mixed forest

Mixed evergreen forest are located around the Mediterranean Sea and the Black Sea. Typically, the summers are warm or hot and winters mild. The mean temperature of the warmest months ranges from +10 to 35 °C and that of the coldest month from +2 to 18 °C.

In the Mediterranean region, the annual precipitation minus potential evaporation differs greatly from that in the broadleaved deciduous forests. It is the climatic factor most effectively restricting the growth of trees. Only fragments remain of the rich and continuous evergreen forests which covered the Mediterranean as true climatic climaxes at the beginning of recorded history (Thirgood 1982). Consequently it is difficult to determine the tree species composition of the original natural forests. Evergreen oaks (*Quercus sp.*) are the characteristic natural trees in the lowlands. In addition stone pine (*Pinus pinea*) and Aleppo pine (*Pinus halepensis*) grow in scattered and small groups and Italian cypress (*Cypressus sempervirens*), sweet chestnut (*Castanea sativa*) and olive trees (*Olea Europea*) are also characteristic of the region.

The average growth rate is 4 to 6 m3/ha. Yields barely reach 2 to 4 m3/ha in the closed forest of the driest climate, but the yield can be about 15 m3/ha on irrigated sites and the Atlantic coast.

3.6.3 Past and Present Forest Use

Under natural conditions, and before the significant influence of man, forest covered 70 to 80 % of Europe. The coverage was nearly 100% on the central plains and hills. Now the forest cover is 27% and only 5 to 10% in the most densely populated areas (Kuusala 1994).

During the last 2000 years, 4000 years in the Mediterranean, man has drastically exploited forests, cleared them for fields, pastures and built up area, or reduced to scrub land. Most of the current forest ecosystems are quite different from those of the natural forests. They are at best plagio-climaxes maintained by silvicultural and logging measures. Their tree species composition, density, age structure and biodiversity are artificial. The last natural forests are only scattered remnants in the highest mountains.

Decreasing and degrading forests led to a shortage of wood and the loss of the protective benefits of forest coverage . As a result, the idea of regulated and sustain yield forestry emerged in the 16th century in Central Europe and was further developed on the basis of research and experience in the 18th and 19th centuries. Sustained yield forestry was articulated in the laws of the German states and France in this period. Many other European countries including Denmark, Italy, Switzerland and the United Kingdom were also making significant contributions to the development of mechanisms for the control of forest use. Today, the forestry statistics for central Europe indicate an increase in the growing stock (Richards 1987) and a possible increase in roundwood production (Apsey and Reed 1994). The uses of the forest in this area is typically characterised as multi-purpose, since high population densities requires the production of many forest goods simultaneously (Grayson 1993). However there is an increasing demand for the protection of certain areas from commercial uses in many countries (Grayson 1993) and plantation forestry in Europe is continuing to expand. The growing importance of the non-wood functions of the forest is evident in all the countries of Europe (Hummel 1989).

In the southern portion of Europe, the Mediterranean world, the forest today stands as an example of the consequence of inappropriate forest harvesting. The wood was extracted by means that left the site with high exposure to sunlight, the soils to erosion from desiccating winds which combined destroyed the ecological basis for forest growth. The ancient attitudes were in fact hostile towards forests (Kuusala 1994, Thirgood 1981, Hughes 1975). In the Mediterranean the degradation of forest continues for a host of complex reasons. They include: ignorance of natural processes and impacts of technologies, cultural patterns, poverty, over-population, weak government, apathy and the lack of public policy in the conservation of natural resources (Thirgood 1981).

3.6.4 Area, Volume, and Harvest Levels

The total area in Europe, given the countries included, is estimated to be 500 million ha on which there is a total growing stock of approximately 16 billion m3 of wood. The annual total forest harvest is approximately 325 000 000 m3.

There is a range of timber volume harvest estimates because of changes in political boundaries, difference in years when data was collected, differences in measurement of volume (e.g. inside bark, outside bark), and the comprehensiveness of the definition of timber supply (e.g. industrial versus total wood supply). Table 3.6 represents a collection of the most recent statistics available.

The growing stock in Europe has increased by 40% since 1950 and 16% since 1980. Some of this is a result of improving inventory, where underestimates of 20% or more were common (Kuusela 1994). The harvest levels in Europe have increased by 25% since 1950 and 4% since 1980. Above average increases were recorded in Alpic Europe largely because of the expanding Austrian timber industry. However, harvest levels have declined as a proportion of annual growth, given the increase in growing stock. This suggest that AACs. If they were calculated, would have increased since 1950 and the harvest would have represented a decreasing proportion of the AAC, subject to changes in the amount of reserve and protection forest area. The proportion of coniferous timber harvested has been increasing on average throughout Europe. In 1950 conifers accounted for 58% of the total harvest volume and in 1990 the proportion was 65%. The Atlantic and eastern Mediterranean sub-regions experienced the most dramatic increase in conifer proportion; rising from 30 and 20% in 1950 to 86 and 57% respectively in 1990. This is mainly due to the increase in the number of plantations in these sub-regions. In some sub-regions the proportion of conifer declined marginally during the same period.

Apsey and Reed (1994:68,70,72) estimate the European industrial harvest as 206 million m3 on a roughly equivalent area basis. This suggests that the non-industrial timber use is approximately 37% of the total harvest. For example, fuelwood in Austria represents over 20% of total harvest volume (Richards 1987). Other non-industrial uses include fodder, fence-posts, charcoal and building materials. The proportion of non-industrial timber in the harvest that was estimated above, appears to be too high because it is unlikely that 17% of the total harvest can be attributed to non-fuelwood, non-industrial usage.

TABLE 3.6 OVERVIEW OF FORESTS IN THE EUROPEAN REGION.

State /Province	Total Land Area (000 ha)	Productive Forest Land Area (000 ha)	Proportion of Forest Land Privately Owned (%)[4]	Total Growing Stock (000 000 m3)	AAC (000 m3/yr)	Actual Harvest (000 m3/yr)
Albania	2,780	909	-[5]	72	-	2,108
Austria	8,385	3,330	80	967	-	18,780
Belarus	20,800	5,300	-	761	15,900	9,000
Belgium	3,131	620	58	90	-	3,326
Czechoslovakia (former)	12,789	4,605	0	1,000	-	19,340
Denmark	4,300	419	61	55	-	2,287
Estonia	4,500	1,907	-	240	-	3,250
France	54,919	13,535	74	1,801	-	52,735
Germany	35,562	9,852	34	2,674	-	47,772
Greece	13,204	2,289	7	149	-	3,376
Hungary	9,304	1,626	1	280	-	7,034
Ireland	6,889	320	22	31	-	1,444
Israel	2,031	80	4	4	-	69
Italy	30,126	4,390	60	744	-	8,600
Latvia	6,400	2,248	-	351	-	6,202
Lithuania	6,500	1,610	-	288	-	3,429
Luxembourg	259	82	54	20	-	360
Moldavia	3,400	100	-	17	600	400
Netherlands	4,116	287	55	50	-	1,480
Poland	31,268	8,470	19	1,385	-	23,142
Portugal	8,800	2,309	83	150	-	11,670
Romania	23,950	5,413	-	1,202	-	15,950
Spain	50,471	6,395	65	463	-	15,584
Switzerland	4,129	1,196	27	365	-	7,440
Turkey	77,945	6,642	0	759	-	17,152
UK	24,411	2,325	57	247	-	6,500
Ukraine	34,400	3,900	-	688	16,100	14,500
Yugoslavia (former)	25,600	10,962	30	1468	-	22,021
TOTAL	510,369	101,121		16,321		324,951

Sources: Kuusela 1994, Prins and Korotkov 1994, Nilsson et al 1993, FAO/ECE 1985.

3.6.5 Sustained Yield Timber Management in Europe

[4] These estimates are only available for some countries and in some instances have changed dramatically since the date of publication in 1985 (FAO/ECE 1985).

[5] dash indicates an unknown number.

In earlier times, particularly in central Europe, shifting cultivation was the most common form of harvesting and as long as there was little population pressures it was a sustainable system. The trees were cut, the land farmed for 2 to 4 years and then left to reforest. This method made an extensive use of the land. It required much more land area than current agriculture systems to produce an equal amount of produce. When combined with agriculture and the production of fuel and utility wood, the rotation was c. 30 to 40 years.

Later with population increases, the target of land managers was the sustained yield of wood. This meant there was regeneration after final harvest, the tending of seedling stands, silvicultural thinning to harvest wood otherwise lost by mortality and growing improved, fully densed stand to maturity and final harvest. Other forest objectives included afforesting lands growing scrub vegetation, converting coppice into high forest and producing acorns and beech nuts for swine grazing.

The widespread desirability of traditional sustained yield forestry was expressed by Franz Heske in 1938:

> For all time, this century (nineteenth) of systematic forest management in Germany, during which the depleted, abused woods, were transformed into *well-managed forests with steadily increasing yields, will* be a shining example for forestry in all the world.(Lowood as quoted in Harrison 1992:122).

Today, for example in Germany, the principle of sustained yield still flourishes although in a different form. The concept of sustained yield and permanence, which was formerly applied only to the production of timber, has since been extended to cover all the functions of the forests, that is to say its commercial, protective and recreational functions, and is the guiding principle of all forest measures. In practise the principle of sustained yield is interpreted narrowly or more freely, depending on the particular forest and ownership circumstances involved (Klose 1985).

3.6.6 Ecosystem Management in Europe

Most European forests have been heavily influenced by humans for periods ranging from centuries to millennia. Wetlands have been drained, forest structures has been simplified, fire has been severely curtailed as an influence, wildlife populations have been greatly modified and most forests have experienced some degree of timber harvesting. Given these many repeated interventions of many types, it is difficult to describe an appropriate, 'original' forest ecosystem for the forest types of most of Europe. Until this is done, it is difficult to prescribe ecosystem management practises for a particular area. In many cases, the social and environmental costs of the restoration process may simply be to 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 forest 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:

- Find ways to re-connect fragmented forest areas.
- Identify ecosystem types that are threatened and preserve them.
- Apply restoration ecology principles where required.
- Increase plant and animal diversity at both the landscape and site level in most forest areas.
- Match tree harvesting practise to the natural developmental characteristics of the forest.
- Leave more coarse organic debris on forest sites.
- Continue to apply mitigative factors to reduce the influence of human pollutants.
- Allow a portion of standing volume to be depleted by natural losses.
- Restrict grazing to allow the natural regeneration of forests.

There are many complex social/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 generalise across Europe since, between nations, there are frequently different attitudes towards forests and forested areas. Therefore the authors chose to commission a study of Austria as just one example of efforts to adopt ecosystem management (See Appendix 1).

3.7 Former USSR (Excluding Ukraine and the Baltic Republics)

3.7.1 Geographic Location

Both the European and Asian parts of the former USSR are enormous in extent. The European part extends from the Arctic Ocean in the north to the Black and Caspian Seas in the south, from the Baltic states in the west to the Urals in the east. The total territory is about 430 million ha, of which about 143 million ha (or ca. 33%) is classified as forest land (Nilsson et al., 1992).

Siberia, for the purposes of this report, consists of the Asian portion of the Russian Federation, extending from the Ural Mountains to the Pacific Ocean, from the Arctic Ocean to Russia's southern border with Mongolia, China, Korea, Afghanistan, etc. The Siberian landmass covers some 1.18 billion ha, of which 711 million ha (or 60%) is classified officially as forest land (Shvidenko and Nilsson, 1994; Nilsson et al., 1994).

3.7.2 Major Forest Types

Some 85% of the forest area of Siberia is dominated by coniferous species (notably pine (*Pinus sylvestris*), spruce (*Picea abies* and *P. sibirica*), fir (*Abies sibirica*), larch (*Larix sibirica* and *L. dahurica*), and cedar (Pinus sibirica and P. koraiensis). The remainder is dominated by broadleaved deciduous, divided into hard deciduous at 2% of the total forest area (mainly oak (*Quercus* spp.) and beech (*Fagus* spp.), and soft deciduous at 13% (mainly birch (*Betula pendula* and *B. pubescens*) and aspen (*Populus tremula*). Pine dominates in West Siberia, while larch dominates in the other two regions. The soft deciduous species are well distributed across the three regions, while the hard deciduous species are concentrated in the southeast corner of the Far East.

In Russian Europe, about 2/3 of the commercial forest area is dominated by conifers, 31% by soft deciduous species, and 3% by hard deciduous species.

3.7.3 Past and Present Forest Use

In Siberia, forest exploitation accelerated following W.W.II for the purpose of supplying West Russian mills with raw material. This was essentially cut-and-run exploitation (Shvidenko and Nilsson, 1994). While both legislation and public sentiment favoured sustainable forest management, action did not match the words. The industrial and transportation infrastructure for timber production and utilisation are now outmoded and inefficiently located (Shvidenko and Nilsson, 1994), so much so that only about 30% of the commercially exploitable forest can possibly be accessed. Wood waste levels are high in the forest, during transportation, and during processing.

The 1990s have so far been characterised by large changes and much uncertainty in Russian forest management, economics and policy. New legislation was enacted in 1993 and forest administrations have been reorganised. Key unresolved issues include clearer definitions of property rights and decision-making authority, especially as they affect the federal and local government levels, and the securing of funds to support sustainable forest management.

For some time, the Russian forests have been harvested at rates well below AACs (Shutov, 1995). This continues today, and the possible reasons include: (a) too many authorities involved in forest decision-making; (b) inefficient and ineffective administration; (c) deforestation and overharvesting; (d) mismanagement and lack of silviculture; (e) lack of skilled labour; (f) forest fires and diseases; and (g) inefficient and poorly located industries and transportation networks (Nilsson et al., 1992).

Non-timber forest products and services produced in Russia include fruits, berries, nuts, mushrooms, tree sap, medicinal plants, grazing, hay, honey, hunting, fishing and recreation. It has been estimated that some 50% of non-wood products in Siberia are physically accessible for exploitation and that annual harvest rates are generally at about 1-7% of the total stocks.

Cedar (*Pinus sibirica, P. koraiensis*) is an important forest type for nut production, yielding some 1 million tonnes annually. While cedar dominates in only 6% of the Siberian forest, half of the Siberian harvest of sable and squirrel fur comes from this forest type.

Almost half of all medicines in Russia are produced from plants. West Siberia alone has more than 700 medicinal plants in its forests and bogs. Big game species (e.g., elk, deer, and moose) are important sources of food for Siberian people. Some 300 million ha of the northern tundra and forest tundra are designated as "deer pastures".

3.7.4 Area, Volume, and Harvest Levels

Russian forests are vast in area (see Table 3.10), and the average growing stock per hectare, in stocked forests, is roughly 110 m3 in Siberia and slightly higher in European Russia. Total harvests are now much lower than total AACs (see Table 3.8). As recently as 1993, the actual harvest in Siberia was about 70-75 million m3 (Shvidenko and Nilsson, 1994), while the AAC was about 350 million m3 (Nilsson et al., 1994). Thus, actual harvests have been as low as about 20% of AAC (Shutov, 1995). Future increases in harvest levels will depend on many things, including solving the administration, property rights, funding, transportation infrastructure, industrial capacity, and market problems. AACs for Siberia have been predicted to remain roughly at their 1990s levels for the next decade or two (Nilsson et al., 1994).

TABLE 3.8 OVERVIEW OF FOREST SIZE AND HARVEST LEVEL IN THE FORMER USSR BOREAL FOREST REGION

State /Province	Total Land Area (000 ha)	Productive Forest Land Area (000 ha)	Proportion of Forest Land Privately Owned (%)	Total Growing Stock (000 000 m3)	AAC (000 m3/yr)	Actual Harvest (000 m3/yr)
Eur-Russia	529,200	173,800	0	20,200	239,000	191,900
West Siberia	242,700	95,500	0	10,800	103,500	22,600
East Siberia	412,300	255,200	0	29,300	175,600	72,300
Far East	525,800	359,900	0	21,300	106,900	37,900
TOTAL	1,710,000	884,400	0	81,600	625,000	324,700

3.7.5 Sustained-Yield Timber Management in Former USSR

All forest types designated for industrial use are subject to final fellings. Final-felling clearcuts, which produce the bulk of the wood harvested, may reach well over one million ha/yr, and most of them are large (from hundreds to thousands of hectares). Some critics of Russian forestry believe that official ages at final fellings are too low, and this inflates the AAC. Across Siberia, actual ages at final felling for conifers range from about 100 to 140 years. Clearcutting in Siberia has low utilisation standards, so much logging debris and standing woody material is left after harvesting.

Timber harvests are concentrated near existing transportation networks, so local overharvesting, especially of pine, is widespread in many southern areas. Heavy equipment is generally used in clearcutting operations, and site conditions following the operations are highly disturbed (Gusev et al., 1995).

The proportion of all regeneration areas planted or seeded (as opposed to assisted natural regeneration), was almost 30% in West Siberia, about 20% in East Siberia, and roughly 10% in the Far East (1992 data). These proportions have all decreased over the past few years. Seedling survival rates in Siberian plantations are usually less than 50% - thus, plantation failure is common. Assisted natural regeneration is widespread (Shutov, 1995) and consists of such treatments as leaving seed trees and protection of advance regeneration. It is often successful, but on the whole the area of adequately stocked forest has been shrinking. Poor regeneration planning and practices give rise to a situation where there is a gradual shift in species dominance from coniferous species to softleaves (broadleaf, softwood deciduous - mainly aspen and birch) on many areas (Gusev et al., 1995).

Thinnings account for about 5% of the total wood harvest in Siberia. This contrasts with rates as high as 20-25% for the Nordic countries, and as low as ca. 1% in Canada. Herbicide use in Russian forestry has declined significantly in the past 10 years, and is unlikely tc pick up again unless foresters and researchers can convince the public that such silvicultural tools are safe and effective (Shutov, 1995). Regarding insect infestations, Russian foresters are way behind in implementing their desired pest-control programs. Prescribed burning is not used in contemporary Russian forest management.

3.7.6 Ecosystem Management in Former USSR

Discussions are ongoing within the Russian forestry community about how to improve forest management. On one hand, these discussions focus on how to revive Russian forest management so that even the customary regimes can be implemented and thus contribute to a revival of the flagging national economy. On the other hand, there are debates about whether contemporary regimes, as laid out in Russian forestry handbooks, are appropriate for 21st-century forest management. For example, Shutov (1995) indicated that forest farming is being considered for strong timber production, thus potentially allowing non-commercial forests, where timber will not be harvested, to expand. In addition, Shutov (1995) claimed that "Russia's foresters are of the widespread opinion that for many conditions partial cuttings . . . more closely mimic natural disturbances."

4.0 Indicators for Evaluation of Forest Management Systems

Indicators are frequently used by governmental and inter-governmental agencies to assess complex attributes. Indicators can be constructed so that they provide a direct measure of some amount (e.g. dollars, timber harvested, or acceptable wildlife habitat), or they may be constructed as indices (e.g. assess habitat quality using a value ranging from 1 to 5) or simply directions of change (i.e. increase/decrease). The complexity of the attribute being measured determines the number of indicators that are required. Ideally, one indicator would be developed to assess each critical aspect of the attribute.

In this project, the two sets of forest management principles will be compared using a set of indicators. The attribute of the principles that will be assessed is their sustainability (or more precisely, the sustainability of implementing these sets of principles). Sustainability is assumed to be the overriding goal of forest management.

One normally thinks of sustainability in terms of whether it is or is not present. If a system is unsustainable, it should be possible to describe qualitatively or quantitatively how far the system is from being sustainable. On the other hand, it is difficult to understand how a system might be made to be more sustainable. In this situation, we lack the information needed to certify whether a forested area is being managed on a sustainable basis. Therefore, the purpose of the indicators is to identify whether management of an area is increasing the likelihood of sustainability or not. This is ultimately a subjective assessment based on the criteria that we think are required for sustainability. There are a wide range of system configurations which are sustainable - the indicators do not help us to identify which configuration is preferable.

Sustainability is broadly defined to have ecological, economic, and social components, which means that a single value or indicator will not be adequate. (In some forestry operations, the overriding goal is to minimise the cost of delivering a given volume of wood to the mill. In such cases, wood cost is the sole indicator required.)

Accordingly, three sets of indicators have been developed: economic, ecological, and social. The economic indicators are concerned with the financial aspects of timber production and management activities. Ecological indicators are designed to assess the degree to which forest resource management retains the ecological processes and patterns within a forest ecosystem. The impact of forest management on the local economy and on the provision of socially desirable benefits is assessed by a suite of social indicators. The indicators are described in more detail below; however the reader must remember that individual indicators may be of limited use in assessing progress towards sustainability.

4.1 Economic Indicators

The following indicators have been classed as being economic in nature:

- Area of exploitable forest land
- Volume of growing stock
- Harvest volume and AAC
- Area clearcut
- Wood value
- Silvicultural treatment costs
- Harvest costs
- Access costs

Each of these indicators is defined and then assessed in the sections below.

4.1.1 Area of Exploitable Forest Land

Description

This indicators refers to the area of forest land that can support harvesting activities now or in the future if the present stands are too young. Land with merchantable timber that is not now accessed but which is expected to be accessed at some time in the further would be included in the value of this indicator. This indicator does not attempt to assess the economic viability of harvesting operations, hence changes in timber prices or technology do not affect the indicator value. If this indicator is rising, then this will increase the flexibility of industrial management, enhancing sustainability provided that the ecological indicators are steady or improving. the area of forest land. A declining value of the indicator is favourable provided that social indicators are not declining too.

Assessment

In regions where the forest is under pressure from industry and conversion to other uses, such as is the case in the more populated areas of the US South and Northeast, then it is expected that ecosystem management will result in a reduction in the area of exploitable forest land.

However, in less populated areas, the reverse might hold as improved forest practices reduce the pressure for land withdrawals. This line of argument was proposed by Booth et al. (1993) for the boreal forest. They reason that a general reduction in management intensity will result in a need to manage a larger area to obtain sufficient timber, and the reduction in negative visual impacts will obviate the need for extensive parks and reserves. However, it is not a requirement to maintain current timber harvest levels; the purposes offered for setting aside some proportion of forest include the provision of wilderness, setting up areas for scientific study and monitoring, and setting aside a proportion (e.g. 12%) of each type of forest ecosystem to preserve genetic diversity.

The adoption of ecosystem management is expected to result in the use of harvesting practices which remove less area from the land base. The Clayoquot Sound scientific advisory panel estimated that the area of roads, landings, and back spar trails will be reduced from roughly 10% of the land area (the figure ranges between 9.3 and 11.8%) to 4.5 % using the skyline method, thus increasing the exploitable forest area. On the other hand, the area of exploitable forest land will be reduced somewhat to meet restriction such as the requirements for extension of the hydroripiarian areas. Therefore, in the western region, the exploitable forest land area should not be reduced substantially under ecosystem management.

4.1.2 Volume of Growing Stock

Description

The growing stock is the volume of standing timber present in a forest; it is a stock measure rather than a flow. Typically, these data are estimated from aerial photographs and are subject to some estimation error. Growing stock volume depends on forest area, stocking, age class structure, and the productivity of the site and the species. There is some range of growing stock levels which is associated with a forest that produces a desirable mixture of values and has well-functioning ecosystem processes. Higher or lower values of growing stock are inconsistent with a desirable forest structure - too much growing stock indicates that the forest has a preponderance of overmature timber whereas too little indicates that the average age of stands is relatively low and/or stocking levels are low.

Most managed forests are harvested when average growth peaks and the trees reach an operable size. Over time, the area of older timber stands shrinks as these are harvested and so the growing stock level gradually declines over time. In forests managed at low to medium levels of intensity, a shift to ecosystem management will increase the volume of growing stock as more partial harvesting is undertaken and as significant areas of forest are managed under extended rotations. Harvest ages will be extended when the objective is to allow the development of "old" stand types and also when management intensity is reduced, since stands of natural origin generally take longer to reach an operable condition than plantations. Seed tree and shelterwood methods leave standing timber for longer periods than would be the case under clear-cutting and two-pass harvesting tends to increase the average timber yield per hectare over time, implying an increase in growing stock.

Assessment

In the boreal forest, it is not clear how much partial cutting will be applied and so the main source of additional growing stock will be the extended rotations. In the western temperate zone, there is currently a high volume of growing stock due to the continued presence of old growth stands. Sustained yield management calls for the eventual liquidation of these stands in commercial timber areas; they will be replaced with younger stands managed at harvest ages ranging from 100 to 140 years. Partial harvesting systems will be employed on much of the remaining old growth, thus mitigating the reduction in growing stock. Significant areas are also likely to be managed on long rotations, further adding to long-run growing stock levels. In the bottomlands forests of the US South, ecosystem management is expected to increase growing stock due to efforts made to increase the density of poorly stocked, high-graded stands, in addition to the reasons listed above. Thus, in all forest types mentioned above, ecosystem management will lead to higher long term levels of growing stock.

However, in the southern US pinery, the reduction in intensively managed plantations that will accompany ecosystem management may reduce growing stock volume. Pine plantations produce much more volume than natural stands over a wide range of ages. Some biologists believe that plantations do not produce any great increase in gross dry matter production, but rather grow it more rapidly and on fewer stems. While this may be true, the net volume available is higher and much mortality is captured from thinnings. Thus, on the whole, growing stock volume will likely decline in this forest type.

4.1.3 Harvest Volume and Annual Allowable Cut

Description

The harvest volume is the actual volume of wood felled and removed from the forest while the annual allowable cut (AAC) is a theoretical maximum harvest level. Williams and Tanz (1994) define AAC as a short-term measure of the volume of timber that the land owner (or regulator) is willing to make available, under current conditions, from a specific area for a specific period of time. The AAC serves as a benchmark that depends on available land area, rates of growth and mortality, age of anticipated harvest, and the harvest technique. The methods of estimating AAC are broadly classed as either volume-based or area-based; any forest management textbook will describe the various methods in more detail. In contrast, harvest volume depends on markets and operational factors as well as physical forest characteristics and harvest technique.

The AAC is subject to subtle differences in interpretation. Most agencies view AAC as the upper biological limit on harvesting, but others view it as the "average" economically accessible harvest volume. The AAC may be higher or equal to the long-run sustained yield, depending on whether the forest growing stock is larger than the level expected under management in the long-run. This latter provision is highly significant in the western North American forest zone because the old growth timber has so much more volume per hectare than the second growth stands will ever have. Thus, while the AAC often serves as an upper limit on harvesting, sometimes harvest volumes are permitted to exceed the AAC for some time. In the discussion that follows, the AAC will be interpreted as the upper biological limit on harvesting over the long term.

Harvest levels can generally be expected to move in same direction as the AAC when harvesting is near or at the level of the AAC. However, when the harvest level is far below the AAC, as is the case in Siberia and with hardwoods in the boreal and western forest zones, then the AAC may harvest level may rise even as the AAC declines. Note that in all scenarios, the distribution of the size of harvest areas will change.

Assessment

In most US jurisdictions, there is no AAC calculated for the forest areas, largely because of the high proportion of privately owned land. However, it is possible to estimate roughly where an equivalent AAC may be located with respect to the harvest level. In the southern US, the harvest appears to equal or barely exceed an equivalent AAC in both bottomland hardwoods and pine. The reduction in plantation area and the increased use of longer rotation systems for pine will both contrive to reduce the AAC and the harvest level. The harvest volume from bottomland forests is subject to a number of conflicting tendencies. The increase in stocking will cause the AAC to rise over time, and harvest levels will likely follow. This is balanced by a decrease in AAC accompanying an increase in rotation age. The effect of shifting from even-aged to uneven-aged management is unclear. A similar result obtains from the Appalachian hardwoods.

The western zone is witnessing some very large reductions in both AAC and harvest volume due to land withdrawals and regulated reductions in harvest activity. (The harvest level often exceeds the AAC due to provisions for harvesting old growth timber and so changes in AAC will immediately affect harvest volumes.) Much forest land is owned by public agencies in this zone, and much of the private forest land is owned by timber companies. The remaining old growth forests are largely on public lands.

Harvesting will be reduced immediately by up to 50% as indicated by the annual allowable cut in Clayoquot Sound. In addition, restrictions on the rate-of-cut and the scheduling of the timber harvest will further reduce the harvest level. For example, in any watershed greater than 500 ha in size, the cut should be limited to 5% of the area within any five-year period. In watersheds, between 200 and 500 ha in size, the cut should be limited to 10% within any ten year period. These restrictions are often not reflected in the AAC calculation but they have the effect of further reducing it.

The boreal forest presents a somewhat different situation, even though softwood harvesting is generally near the AAC level. A key ecological influence on the AAC is the extent of disturbance. Where fire return times are relatively short (e.g. 50 years), a relatively higher level of clearcutting can be maintained, which might equal or even exceed current harvest level. On the other hand, when fire return times are longer (e.g. 200 years or more in the Ontario Clay belt), it may be appropriate to reduce the AAC.

It is not clear how much partial harvesting will be undertaken under ecosystem management in the boreal forest. Booth et al. (1993) feel that the use of partial cutting methods will undoubtedly increase. White and red spruce and white pine are the species most amenable to retention as single trees or in small clumps, since they are relatively long lived (up to 300 years in the case of red spruce and 400 years for white pine (Seymour and Hunter, 1992), relatively windfirm, and can survive exposure once the surrounding stand has been removed. Partial harvesting may also be undertaken to replicate the effects of light burns (or the edges of larger burns), spruce budworm (remove the balsam fir and, to a lesser extent, spruce), and forest tent caterpillar (remove hardwood species). In drier areas (the western section of the region), insect losses are generally less significant than fire losses and so partial cutting would primarily be undertaken to replicate partial burns. The reverse is true in the eastern part of the zone, which is much wetter and more greatly influenced by spruce budworm. Note that harvest levels may rise on some forest management units, fall on others, and remain roughly unchanged in aggregate over the entire region.

In many forest zones, it appears likely that more area will be set aside in reserves, there will be less emphasis on planting, and the age of harvest will be extended in parts of the forest. These factors will all lead to a decline in AAC and harvest levels throughout most forest types in the boreal and temperate zones.

4.1.4 Area Clearcut

Description

This refers to the area of forest on which all merchantable timber is felled in one pass, whether by means of normal harvesting operations or other operations such as salvage cuts. Sometimes, when a forest has species with no commercial value, these trees are left behind simply because there is no market for them and the harvesters do not wish to take the time to fell the trees. These areas should be treated as clearcuts for the purposes of this indicator. However, strip and block cuts and the use of modified methods such as the seed tree system and the variable retention silvicultural system are not counted as clearcuts - these are partial or multi-pass cuts.

From an ecosystem management perspective, the key determinants of the amount of clearcutting permitted are the nature of the disturbance regime and the characteristics of key forest species. These two determinants are closely related. Where large catastrophic disturbances are common, the forest tree species tend to grow best as even-aged stands. A good example of this is the boreal forest. Thus, one would expect to see a significant level of clearcutting continue under ecosystem management in the boreal forest, although the spatial distribution of harvest areas and the range of cutover sizes can be expected to change. The same arguments hold in both the pine and southern bottomland forests where the main disturbances are fire and flooding.

Disturbances tend to affect single trees or groups of trees in the western and eastern temperate forest zones. Common sources of tree mortality include insects and pests, lightening, and wind and ice damage. Wind damage can be widespread and open up significant patches, especially in the eastern temperate forest, but the rates of loss to wind are poorly understood. The harvest of single trees or patches of trees will be the common silvicultural practise.

Assessment

Throughout the eastern and western temperate forest zones, clearcut area will decrease substantially under ecosystem management, due to an increase in the frequency of partial harvesting. Similar results are expected in the southern bottomland forests, where the development of complex, multi-aged stands is very common when natural processes are followed.

In the southern pine belt and the boreal forest, the assessment becomes somewhat more difficult since large fires are common. This is especially so in the western section of the boreal forest, which has a drier continental climate. Southern pines grow largely in even-aged stands but USDA (1965) does mention the existence of uneven-aged stands of loblolly pine. However, fires do not always kill all timber; one often finds patches of unburned or damaged timber on the edges of burns, on moister sites, and other areas where topography or changes in fire behaviour caused light damage. Thus, there is solid ground for arguing that some portion of the harvest area in the boreal and southern pine forests should be partially cut.

People will also argue that fires have many different ecological impacts compared to clearcuts, most notably concerning the effects on the littler layer and the fate of woody material and the nutrients therein. This is indisputable. However these differences do not generally argue in favour of more partial cutting; instead they suggest a greater role for prescribed burns and the need for changes in harvest technique.

Finally, it should be noted that the lengthening of rotation ages associated with ecosystem management will tend to reduce total harvest area (and, accordingly, clearcut area) and this trend is reinforced by the overwhelming negative public perception of clearcuts. The net effect of these factors is expected to be a significant decline in clearcut area in western and eastern temperate forests and the southern bottomlands and a minor decrease in the southern pine belt and the eastern boreal forest. There should be no change in the western part of the boreal zone.

4.1.5 Wood Value

Description

This indicator is concerned with the value of standing timber. When the dominant use is industrial, the value of standing timber can be estimated as the difference between the value of timber products delivered at the mill and costs of harvesting the timber and transporting wood to the mill. The costs of minimum required silviculture and an allowance for profit and risk should also be factored into these calculations. Thus, in a purely industrial setting, timber value reflects the volume of various roundwood products (e.g. veneer bolts, sawlogs, pulpwood) that can be produced, as well as the location of the stand vis-à-vis the mill. The indicator value should be an average value across the entire harvest volume. However, standing timber has a myriad of non-industrial values and in some situations these can be expected to exceed timber values. Unfortunately, non-industrial values are very difficult to assess.

Assessment

Over the longer term, wood value is likely to rise on average throughout all zones except the southern pine area due to a shift towards the production of larger pieces of roundwood (which has a higher value). The use of longer rotations on a portion of the forest and, to a lesser extent, the increased use of alternate harvest techniques will lead to an increase in the proportion of large piece sizes in the timber supply. For example, the modified clearcutting (e.g. seed tree) and shelterwood, and selection systems all offer the potential to produce some large timber. In the NA western zone and Europe, there will be a significant increase in potential piece size.

Wood values will also increase where more valuable species will be encouraged. This is particularly the case in the eastern temperate and southern bottomland forests, where the most valuable species have been depleted due to high-grading. In these forest types, there will be an improvement in stem quality as selection and shelterwood management are instituted more widely. On the other hand, there will also be some effort made to retain non-commercial species ,which will lower average wood value. These efforts are only likely to have a measurable impact on wood value where management was intensive enough to severely deplete these undesirable species (e.g. hardwoods and unusual pine species in the southern pine zone, hardwoods in the Nordic area). In addition, reductions in average management intensity can be expected where management is currently very intensive, leading to some decline in wood value. Note that the factors described as causing increases in commercial wood value also tend to raise the value of the non-timber goods and benefits provided by the forest, notably wildlife and aesthetic values, which contribute to higher quality recreation.

A more indirect impact of adopting ecosystem management is the associated reduction in harvest volume, especially in the short to medium term, and the overall balance of supply and demand. Tightening wood supplies and increasing demand for wood fibre based products have already triggered increases in the value of wood and can be expected to continue to do so in the future. Withdrawals of large forest areas from commercial availability in the western temperate zone are often cited as major contributing factors. These withdrawals were largely attributed to a desire to maintain habitat for the spotted owl but the owl came to symbolise the loss of irreplaceable old growth forests and so represents the spectrum of concerns at the root of interest in ecosystem management.

4.1.6 Silvicultural Treatment Costs

Description

For the purposes of assessing this indicator, silvicultural treatment costs are the average annual, post-harvest costs of regenerating stands and ensuring that they are established. Operations such as site preparation, herbicide application, prescribed burns, seeding, planting, and follow-up stand tending should be included with this indicator. Costs of addressing regeneration failures and of assessing regeneration success should also be included. It is too difficult to forecast at this time how ecosystem management will affect the application of silvicultural activities to established stands (thinning, protection from insects, etc.) and so these activities are excluded from this analysis. One may argue that additional harvesting costs borne in order to fulfil silvicultural functions should be considered as silvicultural costs. In theory this argument makes sense; in practice it is difficult to break out and attribute different portions of harvest costs to various objectives. As a result, the cost of measures taken during the harvest operation are covered by the harvest cost indicator.

Silvicultural cost is often viewed as a proxy for management intensity; timber growth rates and yields should be a non-decreasing function of silvicultural cost. In isolation, the direction of change in silvicultural costs has little direct bearing on sustainability since there is a variety of forest management configurations (and therefore a range of silvicultural costs) that are sustainable. An economist would suggest that it is unsustainable to undertake silviculture when the costs exceed value of the timber and non-timber benefits arising from the treatment. The difficulty here is in assessing the value of non-timber benefits.

Assessment

It is likely that total silvicultural costs will decline under ecosystem management, although some activities will be performed more frequently and other activities might be performed in a different manner at greater expense. In all regions, the greater use of partial harvest systems (and therefore natural regeneration), the shift away from stand conversion measures, and the general lessening of management intensity on the overall forest all point to a reduction in silvicultural costs. The most widespread shift from clearcutting to partial cutting is expected in the western and eastern temperate regions. Consequently, the largest reductions in silvicultural costs can be expected in these regions. This outcome will be reinforced if the harvest volume is allowed to decline. On the other hand, the area in the forest in which partial and full harvest operations are conducted in any one year will be larger unless the harvest volume declines significantly.

The same considerations apply, but with less force, to the boreal and southern pine forests. However, prescribed burning might be more widely practised to suppress hardwoods in these forest types, which will increase costs. Limited increases in the use of prescribed fire are feasible but it is often difficult to implement a large number of prescribed burns because favourable burning weather usually coincides with a large number of unwanted fires. Suppressing these is the first priority of fire suppression units, which means that they are unavailable for prescribed burns. In addition, there may be some resistance within the fire management organisation to deliberately set fires; that seems to go against the organisational mandate. Finally, prescribed burns require appropriate fuel conditions, which change as the tops and slash break down and as herbaceous plants occupy the site. Thus, if circumstances prevent the use of prescribed fire for two or three years, then usually some other site preparation method must be adopted.

Another potential source of increased silvicultural expenses is increased reliance on manual and mechanical means of releasing stands from competition. Under ecosystem management, a reduction in the use of chemical measures can be anticipated. Chemicals are often aerially applied, which leads to very low costs of application. Manual release can cost from 5 to 8 times more per hectare and a shortage of manpower limits the area that can be treated.

In summary, silviculture costs are largely expected to decline. The principle reason is that there will be an increased reliance on natural regeneration and an overall reduction in management intensity. These reductions are expected to be greatest in the western and eastern temperate zones, as well as the southern US hardwoods. In the boreal and southern pine forests, there appears to be equal scope for the use of natural regeneration but additional prescribed burning and more costly competition management techniques will tend to mitigate the cost reductions in these forest types.

4.1.7 Harvest Costs

Description

The costs included in this indicator are the expenses of planning the harvest, felling the trees, delimbing and perhaps bucking the stems, and transporting the harvested wood to the mill. The indicator value is most easily expressed as an average dollar cost per cubic metre of wood delivered to the mill. There are a great many harvesting systems in place. A company chooses a particular harvesting system based on cost, the type of timber and the primary products that are best handled at the mill, and the type of terrain that will be operated.

Assessment

In the boreal and southern pine forests of NA, a shift to ecosystem management can be expected to result in a different distribution of cut sizes. In the boreal zone, most harvesting is done by clearcutting but clearcuts are generally limited in size to 150 ha or less (actual limits vary from province to province). Under an ecosystem management approach, the distribution of cut sizes can be expected to shift so that a larger number of cuts are relatively small (e.g. 10 - 25 ha). However, there will also be some very large clearcuts (e.g. greater than 500 ha). In addition, more partial harvesting can be expected, especially on wetter sites where blowdown of individual trees or small patches of trees is more common than on upland sites.

In the western and eastern temperate zones of NA, wider use will be made of systems that remove single trees or small groups of trees. These shifts will necessitate some wide-reaching changes in the types of logging systems employed. One of the main shifts will be an increased use of smaller, more manoeuvrable machines, especially in the eastern temperate, boreal, and southern forests. Single grip harvesters will be more widely used; once operators have become experienced with these new machines, productivity does not decline significantly as compared to other systems.

Because trees on the west coast are so large and the terrain so steep, very different harvesting systems have been developed. These too are expected to change to meet the requirements of ecosystem management. For example, the Clayoquot Sound Scientific Panel advocated replacing high-lead and grapple harvest systems with skyline harvest systems, resulting in higher costs. Preliminary research indicates that the falling and yarding phases of timber harvesting will increase significantly and that the overall unit production costs will increase due to higher costs and lower volume removals. Where ground based systems are in use, a shift will be made away from traditional skidders to hoe forwarding which also has a higher logging cost.[6] However, since 80% of the available forest land has more than 60% slope, skyline methods will be used throughout most of the forest. Although these results are specific to the Clayoquot Sound area, they can be generalised to the entire West Coast. The Clayoquot Sound recommendations represent some of the most recent analysis of expected shifts in logging costs to meet ecosystem management goals.

[6] Hoe forwarding is done by transporting the logs without dragging them on the ground. An old back-hoe is modifed for this purpose.

In Europe, final-felling will become more common since it is seen as a tool for creating appropriate conditions for tree regeneration and natural stand development. Due to smaller units of timber harvested per unit of forest land, harvesting costs are expected to increase. Except on sites unfavourable for treatment, no lower economic limits on the harvesting size are expected.

The adoption of ecosystem management will also change the distribution of harvest activity throughout the forest. Harvest efforts are likely to become more widely scattered across the forest, especially where many disturbances are small in scale. As harvest area sizes decrease and as harvesting becomes more widely dispersed, costs will increase. Harvest allocation plans calling for one or two small clearcuts located far from the mill and far from other operations are not likely to be economic. Thus, the application of ecosystem management will be limited by the set of economically feasible activities.

4.1.8 Access Costs

Description

Access costs refer to the expenses of planning, constructing, maintaining, and perhaps retiring forest access roads. Costs of access for industrial activities as well as for recreational and other purposes should be included in this indicator. The data generally permit the inclusion of the full range of access purposes because most forest access roads are initially constructed to haul timber or for mining. Once these roads are built, many people use them. On public lands, access is virtually unrestricted and large private landowners see recreationists as providing a source of income. Many forest areas in the southern and eastern temperate zone are almost fully accessed, and so this indicator is of minimal use in these regions. However, there are many boreal and western temperate forest areas where access networks cover only a portion of the landbase.

Increasing forest access is beneficial in the sense that it allows a manager greater flexibility to allocate activities, facilitates monitoring of forest conditions and response to fire, pest outbreaks, etc. An expanded system of access roads may increase the value of recreation opportunities or it may decrease their value, depending on how quality is related to access and level of use. The value of these benefits is difficult to compare against costs.

Assessment

Access costs are likely to increase since harvesting will be more evenly distributed throughout the forest unit (Booth et al., 1993) and perhaps some upwards realignment of the proportions of road length in higher quality classes (and thus more costly to construct). On the other hand, it may be possible for industry to make greater use of winter roads, especially in the boreal zone, which are generally impassable at other times of the year. This may be advantageous when use pressure is high in a general region and there are few non-roaded areas left.

In the western temperate zone, road access costs are expected to decline in the long run with wider use of the skyline system. The Clayoquot Sound Scientific Panel reports studies that calculate that grapple and high lead use 9.5% and 7.4% respectively, of the land area for roads whereas the skyline system results in 3.5% of the area being roaded. However, in the short term, the road network for the area will have to be built much more quickly in order to harvest an allowable volume within the area or rate-of-cut constraints.

In all forest zones, increased partial harvesting will necessitate extended periods of road use and timber harvesting will be spread over a larger area. Thus, a larger road network will have to be maintained at any one time, resulting in significantly increased road maintenance costs.

4.2 Ecological Indicators

For assessment of the various ecosystem management proposals, we have chosen a small suite of ecological indicators based on our understanding of the literature as to the most important ecological issues that ecosystem management has been designed to address, that appear in various documents on criteria and indicators of sustainable forest management, and that most forest analysts seem to be concerned about. The indicators include:

- Biodiversity - in many descriptions of ecosystem management and sustainable forest management, biodiversity is seen as both the most important and the most complex ecological concept to manage for. Biodiversity therefore receives the most in-depth treatment below.

- Soil condition - soils are not only home to thousands of forest-dwelling species, but also provide the essential substrate for tree growth and determine, to a large degree, overall biotic productivity of the forest ecosystem.

- Water regime - water movement among various ecosystem components - mainly the atmosphere, the vegetation, the soil, the subsoil, and water bodies - is of concern in overall ecosystem functioning.

- Water quality - this is included mainly because people are concerned about fish habitats and potable water supplies from forest watersheds.

- Carbon storage - this is of concern because of the strong exchanges of carbon between forests and the atmosphere. Carbon is a major contributor to the so-called greenhouse effect.

4.2.1 Biodiversity

Description

There is a growing and widespread concern for the variety of lifeforms on earth. In the past decade, the emerging label for this concern has become biodiversity, or biotic diversity. Biodiversity represents a collecting place for a wide range of issues regarding the variety of life. Not only does it capture the issue of species extinction, but it also includes the conservation and use of genetic resources, species migrations and introductions into ecosystems beyond historical limits, and others.

Most literate citizens of the world, at least in the so-called developed countries, hold the view that biodiversity conservation is important. Indeed, the world community has formalised this concern into an international agreement called the Convention on Biological Diversity (CBD). Much of the biodiversity debate focuses on forests, and much of the forest sustainability debate focuses on biodiversity conservation. Thus, conservation of forest biodiversity firmly links two broad spheres of concern about the global environment. And it does so throughout the world. Major attention to forest biodiversity is not reserved only for the threatened, species-rich tropical rainforests, nor for the spectacular temperate rainforests of North America's west coast. It extends to all types of forest ecosystems around the globe, not the least of which are the temperate and boreal forests.

There are many definitions of biodiversity. "Bio" refers to life, and "versitas" in Latin means variety (Canadian Forest Service 1994). Thus, biodiversity means variety of life. We shall use as our starting point in this study the definition contained in Article 2 of the Convention on Biological Diversity (Glowka et al. 1994):

> "*Biological diversity*" means 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.

Most people agree that biodiversity has many facets. Kimmins (1992) spoke of: (a) genetic diversity; (b) within-ecosystem species diversity (so-called alpha species diversity); (c) among-ecosystem species diversity (beta species diversity); (d) within-ecosystem structural diversity; (e) among-ecosystem structural diversity; and (f) temporal diversity. Noss (1990) presented a hierarchical characterisation of biodiversity, with two axes forming a matrix. One axis is composed of composition, structure, and function, and each of these sets of ecological attributes can apply at each of the following four scales: (a) regional landscape (or forest, for our purposes); (b) community/ecosystem (stand); (c) population/species; and (d) gene pools.

Thus, forest biodiversity includes myriad ways of realising and characterising the variety of life in forests. Included are the composition and structure of biota, as well as the processes in which organisms are engaged and which affect them, and, most significantly, the ecosystems that form the habitat for organisms and are defined in terms of both biotic and abiotic elements.

To make biodiversity an operational concept in forest science and management, it is necessary to be explicit about what is considered to be part of it, and how the parts or elements are to be measured. Let us begin with the last part of the CBD definition: "this includes diversity within species, between species, and of ecosystems":

- diversity within species - this deals mainly with genetic variability within species;

- diversity between species - this deals with various measures related to comparisons of species with each other, including uniqueness, abundance, richness, range, etc.;

- diversity of ecosystems - this deals with variation of ecosystems and ecosystem complexes at various scales, depending on the area under investigation.

In biodiversity conservation strategies for countries or states/provinces, it is impossible to set precise, quantified targets. Rather, general statements that describe broad directions to be pursued are most appropriate. Most such statements are variations on the following theme: "to conserve biodiversity". The Ontario Ministry of Natural Resources (1994) followed the recommendation of the Ontario Forest Policy Panel (1993):

"to ensure that current natural biological diversity of forests is not significantly changed and where necessary and practical, is restored".

This kind of goal statement speaks to the benchmark against which future biodiversity conditions will be assessed (i.e., current natural), but it leaves open the question of how to measure natural forest biodiversity. At the level of the forest enterprise, where operational decisions that influence future forest structures are made, there is a need to become more precise so managers can design the appropriate action sets. A strong set of forest-level objectives for biodiversity conservation comes from the ecosystem-management guidelines for the White River Forest near Wawa, Ontario (Anonymous 1993). In the forest-management plan, the forest managers are, for example, calling for a specific percentage of the area of each so-called working group (defined by the dominant tree species) in stands older than the official rotation age, and a specific smaller percentage of the area in stands older than 1.5 times rotation age. These are the kinds of targets that are needed for foresters to design action sets specifically dedicated to achieving biodiversity conservation as specified.

Given the broad definitions of biodiversity we introduced above, it is no surprise that the biodiversity literature offers a wide variety of indicator proposals. Indicators are measurable components of biodiversity. Combining advice from both Noss (1990) and McKenney et al. (1994) suggests that indicators should:

1. be sufficiently sensitive to provide early warning;
2. be widely applicable;
3. be capable of providing a continuous data over wide ranges of stress;
4. be relatively independent of sample size;
5. be easy and cost-effective to measure;
6. be able to distinguish between natural variation and anthropogenic stress;
7. be relevant to ecologically significant phenomena;
8. be amenable to monitoring using sound statistical design;
9. be measurable with little disturbance to ecosystems and organisms;
10. have long-lasting relevance (therefore, avoid fads);
11. include processes and flows, alongside states and stocks;
12. include some ecosystem components of high public profile;
13. include some integrative ecosystem components;
14. span the full gamut of relevant spatial scales and levels of ecological organisation;
15. be selected as part of an overall ecosystem management process; and
16. be firmly connected to clear management objectives.

To these lists of criteria, we would add that, in our view, indicators are preferably those directly associated with attributes of ecosystems or their components, as distinct from those directly associated with human actions that threaten or conserve biodiversity. In other words, the response is more important than the dose.

There are two fundamental ways in which to conserve forest biodiversity, particularly in connection with habitats of particular species and ecosystem diversity: (a) protected areas; and (b) biodiversity-sensitive forest management where timber is harvested.

A. Protected Areas

Many authors promote the idea that forest sustainability must be supported with a "sufficient" network of protected areas in which timber harvest (and other intrusive activities such as mining and hydroelectric development) do not take place (e.g., Noss 1995). The types and amounts that would constitute "sufficiency" are open to much debate and uncertainty. Protected areas in most forests of the world can only cover a small fraction of the total forest area (say, from a few percent to 10-20 percent). This is because governments are usually choosing to keep most of their forest areas in actual or potential timber production.

In this report, "protected area" refers to forest areas in which timber harvesting is not permitted (other forms of human intervention may also be forbidden, but here we are concerned only with timber harvest). Protected areas are not free of effects of human intervention, since all of earth's ecosystems are affected by air pollution of one sort or another, and any climatic changes (e.g., CO_2 increases, ozone depletions) that have occurred as a result of human activity. Moreover, wildfire is actively suppressed in most forests in the northern hemisphere, even in protected areas. Thus, protected areas and otherwise unexploited forests are subject to unintentional atmosphere-mediated effects, and the intentional effects of fire suppression, whereas forests where timber is harvested are subject to these same unintentional and intentional effects as well as the effects of timber harvests and associated treatments.

Protected areas in forests are a vital component of any strategy for biodiversity conservation (e.g., Noss 1990; 1995) or forest sustainability (e.g., Ontario Forest Policy Panel 1993). Indeed, to quote Noss (1990):

> "For native biodiversity at the landscape level of organisation, which consists of gradients and mosaics of many community types, big wilderness is the only option. Wilderness and biodiversity need each other".

There are two broad types of protected area: (a) small areas that provide protection for local ecological sensitivities, such as riparian buffer strips, and special habitats such as old-growth stands; and (b) large areas (say, thousands of hectares and more) that may be seen to constitute wilderness.

A stand-oriented approach to ecosystem management is sure to increase the total amount of forest area off-limits to timber harvest. However, these protected areas will be in relatively small parcels (e.g., a whole stand here or there, a riparian buffer strip elsewhere) because of the stand-scale orientation of the approach. In Sweden, large protected areas (e.g., wilderness) will not emerge from a stand-by-stand approach, and will be difficult in some cases because of the intensity of timber management (Laemas and Fries 1995). Stora Skog (1994a; 1994b) calls for creation of some new permanent reserve, so the amount of protected area will go up. The new Swedish forest policy is confusing on this point, but it states that the current 2.8% of the total forest that is reserved "is judged to be too little and more reserves for nature conservation purposes must be set aside, mainly in southern and central Sweden" (Skogsstyrelsen 1994a).

According to Klever et al. (1994), Russia has an outstanding network of so-called zapovedniks, or strictly protected areas. These areas are, relatively speaking, large and numerous (76 in total), and are often surrounded by territory that is effectively wilderness. They conserve populations of more than two thirds of the rare and endangered species listed in the Russian Red Data Book (Klever et al. 1994). Russia's conservation of forest biodiversity using protected areas seems, relative to what other countries have done and can do, rather advanced (Klever et al. 1994).

In North America, many people endorse the idea of setting aside 12% of each major ecosystem type, which over most large areas will result in an increase in the amount of protected area. Ecosystem management also calls for special attention to endangered species and unique habitat features (Grumbine 1994). The combination of these two thrusts implies that there will be more area formally protected under ecosystem management. However, some commentators disagree. Booth et al. (1993) suggested that the wider use of ecosystem management will reduce the need for parks and protected area, hence they expect that the amount of area requiring full protection under ecosystem management will decrease.

B. Biodiversity-sensitive Timber Management

A full program of forest biodiversity conservation must deal in a substantive way with all forests subjected to timber harvest and other manipulations. A most forceful argument is made for this in the programs of Wildlife Habitat Canada (1994), a non-profit foundation dedicated to conserving wildlife habitat. Wildlife Habitat Canada advocates a so-called "100% solution" to biodiversity conservation (Wildlife Habitat Canada, undated). This means that biodiversity is a key management objective in both protected forests and timber-managed forests.

Ecosystem management is focussed heavily on the condition of ecosystems as humans manage and use them. A key principle for many people in implementing ecosystem management is the mimicry of natural disturbance patterns and processes (Duinker 1995a). Such mimicry can be seen simultaneously as an ecological indicator in and of itself, and also as a means for achieving favourable responses in other ecological indicators such as biodiversity.

The conservation of forest biodiversity is indeed the premiere issue behind mimicking natural disturbance patterns, but there are biophysical processes such as primary production, the hydraulic cycle and nutrient cycles which also are implicated. Most discussion about such mimicry has to do with wildfire, but other natural disturbance agents are also emulated, such as windthrow in tolerant hardwood stands.

In Sweden, the whole theme of both stand management for biodiversity conservation and ecological landscape management is one of mimicking natural disturbances, to the degree that this can be done while timber is still harvested in an economically viable way. Indeed, the Swedes have defined the new forest-management regimes such that the models they want to emulate are natural patterns and processes (e.g., MoDo Skog, undated; Stora Skog 1994a; 1994b; undated; Laemas and Fries 1995). Swedish foresters acknowledge that natural patterns and processes can not be equalled when forests are managed for high rates of timber production. For example, MoDo Skog (undated) admitted that, while trying to increase the number of old trees in its forests, the number will remain much lower than if forests were not managed for timber.

In the boreal forest, natural patterns and processes are driven by the large disturbance agents such as fire and insects. From a spatial and temporal point of view, under ecosystem management there should be a relative strong mimicking of natural disturbances compared with traditional sustained-yield timber management, which in essence tried to reduce natural disturbances and variation.

In summary, we observe that the literature consistently specifies biodiversity conservation as a cornerstone of ecosystem management. While subject to wide variety of interpretations, we expect to find biodiversity as a central object of any proposed alternatives to sustained-yield timber management.

Assessment

Given the objective statement for forest biodiversity conservation above, it is appropriate to search for "improvements" in forest biodiversity, and not necessarily "increases". All the literature on this subject points to the desirability of having "natural" types and quantities of forest biodiversity. "Natural" presumably means the state of ecosystems without any human influence, but defining "natural" levels can be problematic (Noss 1995) - all ecosystems across the earth have been influenced to some degree by humans (e.g., global air pollution). Nevertheless, the literature speaks clearly to the desirability of achieving more-natural patterns of forest biodiversity.

If ecosystem management is defined so strongly in terms of conservation of forest biodiversity, then by definition one would expect the implementation of any ecosystem-management proposal to result in an improvement in forest biodiversity, compared with the result of implementing traditional sustained-yield management. The degree of improvement, broadly speaking, depends on several factors, including: (a) the degree to which the kinds of sustained-yield timber management practised in a particular area were contrary to natural biodiversity considerations; (b) the extent of actual implementation of sustained-yield timber management practices; and (c) the strength of an ecosystem-management proposal in moving toward conservation of natural forest biodiversity. Some examples are in order:

(a) Kinds of sustained-yield timber management - In some areas, such as the US Southeast and New Zealand, large areas of single-species coniferous plantations have been established. These forests are dramatically different from the kinds of forests that would grow on these sites naturally. They may well represent an improvement in biodiversity compared to the immediately previous land use (which, for example, may have been marginal agriculture), but they represent a degradation of natural biodiversity if they have replaced natural forests (see: Forest Stewardship Council 1994).

(b) Extent of implementation of sustained-yield timber management - While sustained-yield timber management may be the declared management regime, it may not be practised on the ground as specified. In Siberia, for example, where forests have been exploited for timber, most principles of responsible sustained-yield timber management have been, in practice, violated (Nilsson et al. 1994; Shvidenko and Nilsson 1994). On the other hand, only a small fraction of the vast Siberian forests have been accessed for timber exploitation (Nilsson et al. 1994; Shvidenko and Nilsson 1994), so the unaccessed forests still exist in a quite natural condition despite the declared forest-management regimes.

(c) Strength of ecosystem-management proposals - given the complexity of the biodiversity issue, it is expectable that some proposals for ecosystem management may embody an incomplete strategy for biodiversity conservation. For example, some proposals focus only on within-stand structures, compositions and processes (e.g., Ruelcker et al. 1994), and make no mention of the landscape-scale structures and processes that are also important in determining overall forest biodiversity (e.g., Hunter 1990).

In North America, all schemes and implementations of ecosystem management of which we are aware can be expected to result in significant improvements in forest biodiversity. For example, landscape-level biodiversity was directly addressed in the White River Forest management plan described above. The forest cover types felt to be most at risk are generally mature and overmature conifer stands. The plan called for specific percentages of the landbase being retained under these types of cover, with the percentage being expressed as a degree of change from 1963 (i.e. pre-harvest) conditions. The White River Forest plan did not address the maintenance of stand-level diversity in any detail. One exception was the need for retaining super-canopy white spruce trees. In much of the southern boreal forest, transition species such as white pine, yellow birch, and sugar maple will also be retained and encouraged on a small scale. Seymour and Hunter (1990) also identified a need to restore heavily-exploited species such as red spruce and white pine in the Maine spruce-fir forest, which is similar to the forest in the Maritime provinces. To the extent that partial harvesting methods are adopted, there will be some increase in stand level diversity.

Regarding specific forest-dwelling species of concern, the coarse-filter approach used to regulate the supply of various forest ecosystem/cover types will also provide a range of wildlife habitats in what will be an approximation of the natural frequency. This should increase the amount of habitat for those species that specialise in the ecosystems that are most threatened under sustained-yield timber management. The fine-filter approach, which focuses on specific species of concern and their habitat supply, will see augmentation of the current focus on commercially important vertebrate species such as moose and deer with concurrent and strong attention to rare and endangered species, as well as indicator species such as marten (Martes americana).

To date there has been little effort devoted to restoring species that have been locally or regionally extirpated (e.g. elk, cougar, wolverine) but species that have been much reduced have been accorded significant interest. Newfoundland is home to roughly 150 marten, which are concentrated in the vicinity of the Western Newfoundland Model Forest. The Model Forest is developing a forest management plan which will emphasise maintenance of the marten, and may attempt to increase its numbers. Similarly, woodland caribou

(Rangifer tarandus tarandus) have been pushed out of much of their original range in Central Canada (Racey et al. 1991; Cumming 1992; Cumming and Beange 1993), but remnant herds survive in Manitoba and northwestern Ontario. In both jurisdictions, significant efforts, in both protected areas and in caribou-sensitive forest management, are being devoted to creating habitat for this species to maintain its numbers and perhaps allow for a moderate level of expansion (e.g. OMNR 1993; 1994a; 1994b; Greig and Duinker 1995).

In western North America, implementation of the variable-retention silvicultural system (see: Swanson and Franklin 1992; Scientific Panel for Sustainable Forest Practices in Clayoquot Sound 1995), along with special attention to hydroriparian reserves and log yarding and transportation, are all expected to contribute significantly to improved biodiversity conservation in west-coast rainforests. In the words of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound (1995): "maintaining the natural size- and age-class distributions of trees helps to retain the natural functioning of the forest-dwelling biota and sustain environmental integrity".

In the Nordic countries, stand management for biodiversity conservation can be expected to have beneficial repercussions for forest biodiversity. Specific statements can only be made with respect to particular sites or areas. Generally, the biodiversity-conserving practices all attempt to make timber management more natural from the point of view of species and their habitats. If we can describe stands or treatment areas as ecosystems, then the stand-by-stand approach will lead to improvements in those elements of biodiversity responsive to within-ecosystem changes. Habitat conditions within ecosystems will become more diverse (which is presumed natural), and to the extent that this creates fundamentally different stands than does sustained-yield timber management, then the among-ecosystem diversity will also rise. The stand-by-stand approach will improve habitat for species with small home ranges whose habitat quality depends on within-stand structures that have become relatively rare through sustained-yield timber management.

The ecological landscape management approach has its primary focus on delivering a more natural landscape with respect to the quantities, shapes, sizes and interspersions of forest communities. Therefore, presuming that sustained-yield timber management has resulted in rather unnatural patterns for these landscape variables, the new approach should be expected to make strong improvements in ecosystem diversity.

If an ecosystem-diversity approach is taken in ecological landscape management, then presumably the wildlife species associated with the natural habitat for the area will be favoured. This is sure to change the relative abundance of species compared to the landscape generated under the conventional approach, which essentially paid no heed to landscape-scale patterns and processes from an ecological point of view.

Given the paucity of published proposals for ecosystem management in Russia, an assessment at this time must refer to ecosystem-management proposals for similar forests elsewhere. Let us assume, then, that ecosystem management in Russia would be appropriately implemented along the lines of proposals for boreal North America and the Nordic countries of Europe. In the areas of Russia where forests have already been exploited, we suggest that implementation of ecosystem management will improve the status of forest biodiversity (see Duinker 1995b). Considering the vast forest areas that have not yet been accessed for timber exploitation, implementation of ecosystem management will conserve biodiversity far better that will sustained-yield timber management, but will represent some erosion of biodiversity since these forests are at present about as natural as can be.

In Europe, due to an extended combination of setting aside of valuable forest ecosystems and sustainable multiple use of forests, improvements in biodiversity are expected (Lutschinger, 1993). The number of animal and plant species which are endangered by current forest management amounts to 1,400. Moreover, the genetic biodiversity of forests can only be comprehensively preserved by introducing ecological sustainability and forest preserves. This is particularly true for tree species such as white fir (Abies alba) which need regeneration conditions not provided by clearcutting.

4.2.2 Soil Condition

Description

As the basic medium in which most plants are rooted, and through which most of them obtain water and nutrients, soil condition is a fundamental requirement for sound functioning of terrestrial ecosystems. We can be concerned about many dimensions of soil condition, and in particular here we are focusing on: (a) nutrient status (are the ecosystem-management practices decidedly better at conserving critical soil nutrients?); (b) soil quantity (are the practices better at preventing soil erosion?); and (c) soil structure (are the practices better at preventing compaction?).

Forests intercept rainfall and forest litter dissipates raindrop energy. Root pressure, forest soil fauna and organic acids build soil structure critical for proper water infiltration in fine textured soils. In this way, erosion is prevented by forest cover (Pritchett 1979, Riedl 1984). Forests provide habitat for animals that burrow, aerating soil and improving mycorrhizal inoculation of tree roots that in turn raises a site's productivity (e.g. Maser et al. 1978). Forest litter and atmospheric fallout contribute to raising soil nutrient levels. These features of the forest cover help to build highly productive soil at a rate of 0.6 to 15 mg/ha/yr (Miller et al. 1988).

Assessment

Around the world, sustained-yield timber management has been criticised for the following undesirable impacts on long-term soil quality:

(a) Clearcutting removes much of the organic matter from the site, and site preparation measures may remove additional amounts. The problem becomes especially acute with increased utilisation and whole-tree processing at the roadside.

(b) The short rotations associated with managed plantations (which are usually harvested using clearcutting) do not permit the replenishment of soil nutrients lost during the harvesting process.

(c) Soil compaction, especially on fragile or semi-frozen sites, can lessen growth potential for decades.

(d) Even when performed according to current standards, the construction of roads and accompanying stream and river crossings can cause soil erosion and loss of water quality and fish habitat.

Intensive plantation management is thought to be the management approach that is most deleterious of soil condition, since clearcutting is the usual harvest method and the rotations are short (especially for pulpwood or biomass production). Managers have responded to these fears by improving road and water crossing construction techniques, using high-flotation tires and restricting operations under wet conditions, and scarifying skid trails and landings.

Ecosystem management with an emphasis of maintaining hardwoods and mixedwoods will contribute more to soil fertility than will conifer plantations under sustained yield management. Hardwood roots penetrate deeper into the soil than do those of most conifer species, thus improving infiltration and soil structure. There will be greater diversity of soil fauna associated with hardwood and mixedwood overstoreys, as well as with the care embodied in ecosystem management in treating the forest floor (Wedeles et al 1995).

Given the larger amounts of organic matter to be left on site with many practices associated with ecosystem management, soil condition will generally improve. More organic matter means more nutrients, better water-holding capacity, and erosion/compaction resistance.

There has been some debate over whether pure conifer plantations managed under short rotations reduce soil nutrient status and forest health. Most evidence to date suggests that litter-raking by pre-industrial societies in Europe was a critical causal agent of observed declines in spruce plantation vigour in parts of Germany. Other areas of pure conifer plantations suffer from inadequate drainage caused by weakened soil structure from poor management practices and the shallow rooting nature of the plantation species (Innes 1993).

Regardless of which management system is used, careful logging and site preparation methods and machinery are necessary to guard against soil degradation. Fine-textured soils on steep slopes are clearly the most sensitive to destruction of structure by compaction from machinery. Rutting by machinery can impede drainage or speed erosion. In temperate and boreal forests, many of these problems can be avoided by using specialised equipment (e.g., skidders with extra-wide tires) or by operating in the winter months.

In summary, practices associated with ecosystem management (Franklin 1992) generally contribute to healthy soil development. Perhaps this is the greatest benefit of ecosystem management compared to sustained yield management, and may explain its advocacy by forest ecologists (Kimmins 1987). This is not to say that sustained yield management necessarily damages soil, but at best it may not make as great a contribution toward improving soil as does ecosystem management.

4.2.3 Water Regime

Description

Different forest-management practices, particularly timber harvest, can have quite different effects on the behaviour of the hydraulic cycle. It is widely believed that the main effect of forests upon the water cycle is to reduce the fluctuations in stream flows following precipitation events compared to unforested land. In addition, forests intercept and use water through evapotranspiration, which reduces the water yield in a given watercourse (Riedl 1984). The magnitude of these effects depends upon tree species, geomorphology and climate (Miller et al. 1988, MacGregor 1994). Of concern also is the movement of the water table. Sensitive sites can endure long-lasting changes in the water table upon clearcut timber harvest, changing in a major way the type of tree-dominated community that the site can subsequently support.

Assessment

Tree species affect the water regime by virtue of their crown and root forms that differentially intercept precipitation. Tree species also differ in their physiology, affecting their water consumption requirements for growth and maintenance. In general, although hardwoods can be more demanding of water for growth than conifers, they intercept less precipitation and tend to be associated with higher water yields (Larcher 1991, MacGregor 1994, Riedl 1988). Furthermore, water yields are inversely proportional to plant biomass; thus, closed-canopy juvenile to rapidly growing stands will yield less water to a stream than newly regenerated or older, more-open stands. Lastly, the features of different tree cover types that produce lower water yields are also associated with lower amplitude and longer duration of peak flows from floods (Riedl 1988, Miller 1988 MacGregor 1994)

At a broad-scale view, forest management controls forest cover tree species composition, density (tree number per unit area) and the various stages of tree growth (juvenile to old growth). Sustained-yield forest management tends to favour younger, pure, dense (preferably conifer) forests compared to ecosystem management. Thus, sustained-yield management may reduce water yield compared to ecosystem management. By corollary, sustained yield management can also improve water conservation and avoid floods provided that it is practised on a watershed basis rather than a large administrative area basis. Unfortunately, the latter case predominates in our study areas, with a notable exception being the Pacific Northwest where newly developed best management practices give due regard to watershed-based control over forest operations (e.g. Naiman 1992).

> Mountainous areas with significant relief, such as the western forest and portions of the eastern temperate forest region, are most sensitive to floods induced by changes in forest cover. Flooding increases water turbidity and may adversely affect fish habitats, besides causing property damage and threatening the lives of human inhabitants (Naiman 1992). There are fewer bogs and lakes to help regulate streamflow compared to the other regions in this study. The risk of flooding is even greater in areas with high levels of summer precipitation and shallow soils such as coastal British Columbia.

Studies in the coastal temperate forests of North America clearly show an increase in storm runoff volumes and storm peak flows with timber harvest and associated activities. These effects have been shown to disappear in the absence of roads. Effects are most notable when more than 20% of the watershed is cleared within a decade or two. In addition, the cloud and fog condensation provide significant inputs of water to the system. Tall old-growth canopies are particularly effective at capturing this moisture and thus play an important role in the hydrological regime. Thus ecosystem management in the western region is more effective in protecting the hydrological cycle.

Shallow or impermeable soils on flat terrain common to large areas of the circumpolar boreal forests can also flood when forest cover is removed. These remain localised effects and can impede forest renewal, but have little effect on downstream communities. Under these conditions, partial cutting and other measures related to ecosystem management may actually increase timber yields while mitigating environmental impacts.

Many areas of the boreal forest of NA have water tables which reside at or just below ground level, particularly eastward from central Ontario and also in the northern parts of the zone. These sites have to be harvested carefully, otherwise the moisture regime will change. Current practice is to cut these areas in the winter with wide tired skidders, leaving as much advance regeneration as possible. This approach has become widespread only within the past decade. Increased use of natural regeneration and partial cutting (especially strip and block cutting), can be expected to further reduce disruption of the water regime.

The southern forest region has deep porous soils that may benefit from higher water yields expected from ecosystem management strategies by replenishing aquifers instead of elevating stream flows. It is possible that the higher soil-water infiltration rates may further the leaching of nitrates and other nutrients. However, this may be compensated for by longer rotations and greater representation of hardwoods that are part of the ecosystem-management philosophy.

4.2.4 Water Quality

Description

Forest-management practices can have a profound effect upon the chemistry of forest water. Apart from soil erosion and its attendant impacts upon water bodies, the effects are usually a result of chemically altered groundwater making its way into forest streams, rivers and lakes, and rendering those water bodies less favourable as aquatic habitat and for human use. Nutrient loading is probably the primary element of water quality affected by forest management and soil weathering processes.

Aquatic food chains are highly sensitive to water chemistry. High nutrient loading can encourage a proliferation of plant material that will die in winter and subsequently decompose. This results in reduced levels of dissolved oxygen levels, a condition that may kill fish and other aquatic life. Fish and other fauna can be at direct risk with high sediment and elemental concentrations interfering with the functioning of their gills.

Whereas water yield is a function of broad-scale forest management activities, water quality is a function of both broad- and fine-scale activity. Indeed, water quality may vary directly with changes in peak flows and total water yield.

Water quality appears to be most strongly influenced by the character of stream-side and shoreline ecosystems called the riparian zone. Stream-side trees and plants provide important sources of food to a variety of small animals through leaf, litter and stem fall. Stream-side vegetation shading and sediment load affect water temperature, which in turn influences the quality of aquatic wildlife habitat.

Clearcutting a watershed can elevate stream nutrient loading for several subsequent years. As the site becomes revegetated, levels return to pre-cut values (Johnson 1995). If trees and the forest floor are left as buffer strips, even as narrow as 10-30m, along streams in the riparian zone, they can filter the runoff nutrient flow to acceptable levels, even in intensively cultivated agricultural fields (MacGregor 1994).

Considerable attention is currently given to the management practices in and around the riparian zone (see Singleton et al. 1994). However, water quality and ecosystem connectivity within watersheds respond to cumulative effects of broad- and fine-scale disturbances over time. Thus, consideration of management practices outside the riparian zone cannot be overlooked (Stanford and Ward 1992).

Assessment

Theoretically, ecosystem management should maintain higher water quality levels with less variance compared to sustained-yield timber management. Practices that leave more coarse woody debris (CWD) on site, retain green trees in harvested areas, promote greater tree-species diversity, and are less intrusive during site preparation will help maintain high water-quality levels by reducing sediment loads (Franklin 1992). Also, an ecological landscape management approach would presumably arrange felling areas in space and time in such a way as to protect the quality of water in forest rivers and lakes.

Some promoters of ecosystem management (e.g., Booth et al. 1993; D. Hebert, Alberta Pacific Industries, Alberta, pers. comm., 1995) believe that forest access road systems will need to be expanded to practice ecosystem management. Unfortunately, this will necessitate more stream crossings which may impair water quality (Wedeles et al. 1995). Ecosystem management will therefore demand careful road lay-out planning to minimise stream crossings and to ensure adequate road set-back distances (Daugharty and Douglas 1994).

Both ecosystem management and sustained yield management require careful treatment of riparian zones. If this is done, the impact of sustained yield management on a water quality can be mitigated to approach levels equivalent to ecosystem management. Prompt regeneration of the site will also guard against adverse sediment and nutrient loadings.

Perhaps of greatest public concern is how water quality is adversely influenced by the use of pesticides considered necessary by many foresters for their sustained-yield timber management. Soil-active persistent chemicals like hexazinone will surely find their way into water systems. Foliar herbicides such as glyphosate are more easily contained on the site and rarely will find their way into water bodies if carefully applied. Ten years of watershed-scale research in the southern U.S. have revealed that the short persistence and low concentrations of forestry pesticides do not pose significant risks to water quality and aquatic biota (Neary et al 1993).

In summary, it seems that ecosystem management will allow for greater protection of water quality compared to sustained-yield timber management. Care in road building will be far easier to implement compared to careful execution of management activities linked to sustained yield management such as mechanical site preparation and aerial pesticide applications. Of greater significance may be a shift in managers' attitudes concerning the environment that must be concomitant to adopting ecosystem management practices. A change in attitude will surely lead to greater care in stream crossings and harvesting practices that will result in improved water quality.

4.2.5 Carbon Storage

Description

The carbon dioxide content of the atmosphere is rising, and many climatologists warn that continued rises in CO2 and other greenhouse gases could lead to dramatic climate change over the next century (e.g., Houghton et al. 1990; 1990). Forests are seen as potential major sources and sinks of atmospheric C.

Many argue that forests should be managed so as to serve as sinks, thereby helping mitigate the climate change problem (for a summary, see Apps and Price 1995). We are therefore interested to gauge whether any ecosystem-management proposal could change the ability of a forest to act as a net sink of atmospheric C. We consider, implicitly, the sequestration rates, storage pools, and efflux rates of C in forest ecosystems.

Assessment

The question of whether stand management for biodiversity conservation will improve a forest's ability to act as a carbon sink (and thus slowing the rate of carbon accumulation in the atmosphere) is complex (Duinker 1995c). More standing live and dead trees and CWD leaves more organic carbon on a harvested site. However, if the wood not harvested might have been manufactured into long-term products, it may then have been allocated to longer-term storage than if left in the bush. It is not clear if carbon fixation rates into biomass will be higher or lower under regimes of stand management for biodiversity conservation. However, if fire is used more frequently as a silvicultural tool, it will move carbon to atmosphere quicker than will the cold oxidation of decomposition on the forest floor. Perhaps it is safe to say that the shorter the fire-return interval of a forest type (see Ruelcker et al. 1994), the less one can generalise as to whether carbon uptake and storage will be increased with stand management for biodiversity conservation.

A move towards ecosystem management will have an uncertain impact on carbon storage in the boreal forest (Duinker 1995c). There are a number of conflicting impacts and there is very little quantitative data which permit one to estimate the direction of change. The average growth rate of forests managed under ecosystem principles may well decline as harvest rates fall, the protected area rises, rotation lengths are extended and there is less use of plantations. On the other hand, the change in storage associated with these factors is positive. Yet the degree of increase in storage will be limited by the frequency of disturbance and the trend to changing the forest age-class structure to a reverse-J shape instead of the current bimodal distributions or the "target" normal forest.

In coastal western North America, where fire is not a dominant ecological factor, the carbon storage will likely increase under ecosystem management. In the eastern subregion, the amount of carbon storage will change over time and depend on how fire is used to manage forests. With strong protection of soil resources, the amount of carbon sequestering should also be improved since the soils are not subject to as much erosion, compaction or other damage.

4.3 Social Indicators

4.3.1 Employment

Assessment

Declining employment in the forest sector is a constant concern in many regions. There are several important issues relating to a quantitative assessment of employment and its importance as an indicator: shifts in the employment market due to technological change, the changing nature of forest related employment, the opportunistic character of rural employment, and employment related to a subsistence lifestyle. First, in some regions the substitution of capital for labour has been very significant in the past decade. Thus the reduction in employment in these regions is not due to the imposition of ecosystem management. Separating the employment impact of technological change from ecosystem management is difficult. Second, the definition of forest employment will likely have to be broadened under ecosystem management to include those people in the service sector who rely on forests to conduct their business. This might include, for example, such groups as remote tourist operators and guide outfitters. Third, the work in the forest might require that each worker adapt by assuming different types of different jobs in a defined employment period. This might include different employment within the forest sector or part-time employment in other sectors, such as agriculture in order to make a full employment year. Fourth is the issue of measuring employment related to the subsistence use of forests. This is particularly critical when considering the impacts of ecosystem management on indigenous populations. Maintaining wildlife and fisheries resource under ecosystem based management could keep a number of people gainfully employed in subsistence use. We can conclude that measuring employment and the impact of ecosystem based management will become increasingly complex.

With respect to ecosystem management and on the positive side, the employment due to timber harvesting could increase in all phases of the operation. Increased attention will be devoted to forest planning, requiring a much more diverse team of experts. The use of partial harvesting techniques will increase the number of jobs in all phases. In tree cutting there is an increasing emphasis on getting the maximum value from the log removed rather than the volume removed. In the yarding phase, employment will likely increase with shift to alternative yarding systems. In the western region for example, grapple yarding which is the traditional method of logging with its 2-3 person crews, will likely be replaced by skyline yarding systems using at least 5-6 crew members. The wider dispersal of logging operations due to partial harvesting could require more personnel involved in both road access development and transportation of logs. In silviculture the number of jobs could decrease particularly with the emphasis on natural regeneration silvicultural systems. Thus silviculture workers and wood harvest workers will in effect be combined as forest workers, and silviculture, timber harvesting and ecosystem management will be much more integrated.

Ecosystem management should increase the opportunities to develop small enterprises based on the use of minor forest projects. Also, by virtue of expanding the road system and reducing the incidence of clearfelling, there may be some increase in recreational and tourism uses (although the larger effect will be a re-distribution of use over the landscape). Both of these factors could increase employment.

The net increase in the number of jobs per cubic metre of wood harvested as a result of ecosystem management will have to be balanced against the number of jobs lost as a result of an overall reduction in timber harvest. So, for example, if there is a 20% reduction in harvest levels as a result of ecosystem based management, the proportional loss in jobs will have to be more than compensated by the increase in the number of jobs per cubic metre of wood harvested in order to sustain employment levels.

Another consideration is the shift in timber harvesting operations from one region to another where the jobs/wood volume removed ratio is very different. For example, the western region will have a very different (and higher) job/wood volume removed ratio than the southern US region and if the imposition of ecosystem management shifts the timber harvesting to the US south as some industrialists claim, the overall number of jobs in the timber sector will likely decrease.

4.3.2 Job skill requirements

Assessment

There is general consensus that the skill level of those employed in the forest sector will have to increase with the move towards ecosystem management. This applies at the managerial, planning, technical and field levels.

At the managerial and planning level, the emphasis is on the integration of a much wider body of knowledge than under sustained yield timber management. This requires the use of specialists from a wide range of fields and includes experts in ethnobotany, engineering, history, anthropology, ecology, fisheries and forestry to name just a few. In the western region the use of these experts is vividly demonstrated in areas such as the Tongass in Alaska, Clayoquot Sound in British Columbia and Mount Baker in Washington State. In both management and planning, where there is an emphasis on public participation, it will also be necessary for managers to have better inter-personal skills, since the public will wish to be able to discuss issues with people throughout a government or industry organisation.

At the technical level more complex access plan will have to be put in place, more difficult growth and yield information will have to be compiled, more wildlife habitat will have to be created, more protection to riparian areas, and more integration of competing uses on a temporal scale. In general technicians will have to collect broader and more complex data and monitor a wider range ecosystem functions.

Forest workers will also require greater knowledge and skill level to implement forest management. For example, in the western region, the variable retention silvicultural systems requires workers to have rigging skills to set up the complex skyline harvesting systems and falling techniques to minimise damage to remaining forests. In the northern and eastern regions, forest workers will be required to have more knowledge related to tree quality and species and different skidding techniques. In general, it is necessary to have a more complete understanding of the objectives of forest management and the implications of undertaking activities in various ways.

4.3.3 Worker safety

Assessment

Worker safety is a critical issue in the transition to ecosystem management. Already forest workers are in the highest risk group with respect to worker injury and any changes in management practises which might increase the injury to workers will not be viewed favourably. Ecosystem management could increase injury to forest workers, primarily because the operations are now far more complex and complexity frequently introduces more risk. In the northern boreal region the main harvesting change is with the increased use of single grip harvesters for partial cuts, which will eliminate some operations that use chain saws and skidders. This will improve worker safety. The retention of snags, or coarse woody debris, on cutovers will not raise accident rates for operators in well-protected machine cabs but will pose risks for chainsaw operators and people undertaking follow-up field work. In the western region, the use of the skyline system, which requires more personnel working in dangerous conditions than grapple yarding, reduces worker safety. In addition, fallers using chainsaws will have to leave the 'widow-makers' in place and further increase risk of injury.

The increased use of natural regeneration and the reduction in aerial herbicide and insecticide applications will also contribute to enhanced safety, while the increased risk of fire with retaining coarse woody debris on site could decrease worker safety. In areas where fire is a ecosystem management tool, such as in portions of the northern boreal, western and southern regions the retention of coarse woody debris will decrease worker safety.

In the southern US region, if the manual thinning of forests is increased the incidence of work-related accidents will rise. However, manual thinning is often not economically or logistically feasible, so the impact on worker safety will be minimal.

4.3.4 Diversity of products

Description

Diversity of products refers to number of biophysical products produced for human consumption. This diversity means both a diversity of timber products and the increasing production of many other forest based goods and services such as wildlife, recreation, tourism and other minor forest products. Since ecosystem management will, by definition, attempt to protect a wider range of natural resources the potential diversity of products produced should be increased and the anticipated outcome is that ecosystems will be maintained without degradation.

Assessment

In practical terms and in the northern region, for example, the combination of lengthening the timber harvest rotation period and using different silvicultural techniques consistent with EM, will produce an increasing number of sawlogs and veneer logs of different species. Recreation and tourism products will also be enhanced under EM since more forest land will be deemed suitable for the production of these products at any point in time. Ecosystem management should also encourage the production of non-timber or minor products such as mushrooms, berries, fur, aromatics, cones, medicinal plants and honey (Booth et al., 1993).

In the northern and western regions of North America, the reduction in the number of tree plantations and the use of artificial control mechanism, such as herbicides will help maintain a broader range of ecosystem types, which is consistent with EM.

4.3.5 Non-indigenous people participation

Description

The non-indigenous people participation is simply a measure of public involvement associated with EM. Grumbine (1994), in describing EM, suggests that there is a need to broaden scope of human values that should be incorporated into forest management planning. This need is in response to the growing dissatisfaction with the traditional, industry and government dominated planning approaches. It is felt that in order to implement ecosystem management a new planning process, which includes public participation as a pivotal feature, is necessary because even with a thorough knowledge of ecosystem integrity, those practices carried out in isolation from prior, concurrent or future activities will not provide effective management (SPSFP 1995).

Assessment

Initial assessment of the indicator can be based on examining the frequency of public participation programs now being developed or in place in each region. Overall there is strong evidence in the western, northern and eastern regions that participation rate in forest planning is increasing significantly and this is certainly reflected in the number of public participation programs which have emerged, particularly in the US federal agencies and the provincial agencies in Canada. A dominant principle is that the decisions should be made by those most closely affected by the decisions.

Public participation groups have emerged through a variety of processes, including environmental assessments (Ontario), Model Forests (Canada), community forest programmes (Ontario), Commission on Resources and Environment (British Columbia), Land and Resource Management Planning (British Columbia), Co-ordinated Resource Management Planning (Oregon), Tongass Management Planning (Alaska), and special arrangements for particular areas (Cape Breton in Nova Scotia; Algonquin Forestry Authority in Ontario).

An example of the changes in public participation programs is found in the northern region. Throughout much of the boreal forest, broad forest management objectives are now being set by committees of local citizens representing a range of interests. These stakeholder committees work with government and industry representatives during the planning process and are likely to continue to monitor management and provide input as appropriate at other times.

On private forest land the adoption of EM will likely lead to increasing non-indigenous participation. Although the citizen participants are likely to retain less authority than is the case on public land there is ample evidence of more effective public participation in New Brunswick and Nova Scotia, in Washington state, and at the Haliburton Forest and Wildlife Reserve in Ontario.

4.3.6 Indigenous people participation

Description

Indigenous people participation refers to participation of indigenous people in planning future resource use. In the past, in many regions of the world, their participation was largely ignored and many governments are now trying to correct this past injustice. This means that their rights to use and own natural resources are now being recognized. The solution in many instances lies in some combination of outright settlement in terms of land and money and in participation with government, industry and non-indigenous groups in co-managing the natural environment.

Assessment

Perhaps one of the best current examples of combining indigenous people participation with ecosystem management has recently been reported in the western region, specifically in Clayoquot Sound, British Columbia. The first task of the Scientific Panel, which was responsible for ecosystem management for the area was to establish protocol agreement with indigenous peoples. The protocol agreement reflects the indigenous approach to group processes whereby all members participate in determining the issues, information and actions relevant to planning. It is characterised by a demonstrable and inclusive respect for one another, for different values, and for data founded both in science and traditional knowledge. It has also created an atmosphere that encourages open discussion and the pursuit of consensus. In addition the protocol describes four guiding principles for ecosystem management:

- The world is interconnected at all levels;
- Human activities must respect...all...life;
- Long term ecological and economic sustainability are essential to long-term harmony; and

- The cultural, spiritual, social and economic well-being of indigenous people is a necessary part of that harmony,

Ecosystem based management allows explicitly for the inclusion of traditional knowledge[7] with scientific knowledge. The characteristics of traditional knowledge are:

- *Holism* - all things are interconnected and nothing is comprehended in isolation;
- *Intuitive* - based on deeply held understanding and knowledge;
- *Qualitative* - knowledge is gained through intimate contact with the local environment - based on data collected by resource users through observation and hands-on experience;
- *Transmitted intergenerationally by oral tradition* - teaching is accomplished through stories and participation of children in culturally important activities;
- *Governed by a supreme being* - the Creator defines a moral universe with appropriate laws;
- *Moral* - there are right and wrong ways to relate to the environment
- spiritual - rooted in the social context that sees the world in terms of social and spiritual relations among all life forms.
- *Based on mutual well-being, reciprocity, and co-operation* - these promote balance and harmony between the well-being of the individual and the well-being of the social group;
- *Non-linear* - views times and processes as cyclical
- *Often contextualized within the spiritual* - may be based on cumulative, collective practical and spiritual experience.
- *Communal* - general knowledge and meaning are shared among individuals horizontally, not hierarchically; and
- *Promoting of stewardship* - takes a proactive approach to environmental protection and an ecosystem approach to resource management,

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[7] Also referred to as indigenous knowledge, traditional ecological knowledge, traditional environmental knowledge. It has come to be recognized as an important source of information about species and ecosystems that parallels and complements scientific knowledge.

In Clayoquot Sound there are three major differences between scientific knowledge and traditional ecological knowledge:

- traditional knowledge is profoundly spiritual whereas scientific knowledge abandoned spiritualism.
- traditional ecological knowledge adopts as a fundamental principle that all things are related and interconnected. Scientific knowledge, because of the primacy of repeatable experiments must sever and ignore some natural connections.
- the recipient of traditional ecological knowledge is an integral part of the system, while the researcher of scientific ecological knowledge is deemed to perform best when attempting to behave objectively as a dispassionate observer of the system.

There are two major reasons why traditional ecological knowledge should be more prominent in forest management: its length of experience and complementarity to scientific knowledge. Ecosystem management accepts these reasons and will allow for its inclusion.

In other regions there has been some progress to allow for the inclusion of indigenous knowledge of ecosystem. This knowledge will likely receive increasing recognition in the future in several boreal forest regions.

4.3.7 Range of recreational opportunities

Description

Outdoor recreation is normally classified as consumptive and non-consumptive. The traditional consumptive type of recreation includes hunting and fishing and non-consumptive includes activities such as bird-watching and landscape painting. The classification frequently used is motorised and non-motorised recreation. The former can include the use of boats with power motors and ATVs while the latter can include canoes, and mountain bikes. Irrespective of the classification system used there is widespread agreement that outdoor recreation use has increased significantly in some regions. The measurement of recreation use is dependant on the type of recreation; for example hunting can be measured in hunter days and camping in recreation visitor days. Some regions have standardised the unit of measurement between agencies and other regions have not. For the purposes of this study, we will examine only the number of recreational opportunities available under the old and new EM approach.

Assessment

In the northern region, Booth et al. (1993) suggest that a forest managed using a EM or "lighter hand" approach will offer more and higher quality recreational opportunities on the basis that the aesthetic appeal of the forest will be enhanced and the quality of the recreation product is increased. The expansion and maintenance of access networks, which is predicted in the northern region, will affect the type of recreation uses and may counter the increases just mentioned. For example, the reduction in unaccessed areas is likely to reduce the availability of wilderness oriented activities.

In the western region recreational opportunities could increase with ecosystem management. The evidence suggest that recreational and tourism use pattern[8] are negatively affected by past and present logging associated with sustained yield timber management and users do not generally spend time in areas that are highly altered, especially along the coast where roads are not required for access.

In the southern US region there is likely to be an increase in recreational opportunities as the variety of stand types increase, more older stands are retained, and fewer plantations established

4.3.8 Visual aesthetics

Description

Aesthetics is the perception of the form the mind gives to otherwise undefined essence and created nature (Erzen 1990 as quoted in Bull 1991). Although lacking in a consistent theory, two important methods have been developed to measure visual quality: expert and psychophysical[9]. The current method employed does vary between regions and despite some controversy there are indications that EM does produce a forest area of higher aesthetic quality, certainly at the landscape scale. At the stand level, the visual quality may be reduced but with education, particularly with respect to the benefits of coarse woody debris, the aesthetics response can change.

Assessment

In the northern regions, it is thought that the visual appeal of the boreal forest will be improved under ecosystem management at both a landscape and stand

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[8] It is also anticipated that under ecosystem based management recreation and tourism planning will be integrated in terms of inventory, analysis and planning. This will eliminate the inconsistencies in data collection, data analysis and duplication in planning.

[9] The expert approach relies on the expert judgements of form, line, colour and texture of the landscape elements. The physophysical approach relies on measuring the relationship between environmental stimuli and human sensations, perceptions and judgements.

Two other major approaches to measuring aesthetics are termed experiental and cognitive. The cognitve approach defines landscape quality in terms of feeling and the perception of people who inhabit, visit or view the landscape. The experiental places even greater emphasis on individual subjective feelings, expectation and interpretations of the psychological or the psychophysical. Neither approach has a well defined methodology that could be used in land management at least at this point in time.

level. At the landscape level, the reduction in size and scope of clearcut areas and the increase in partial harvest techniques will improve the appearance of vistas. The dispersed distribution of timber operations will also improve the average viewscape, while perhaps reducing the quality of some. Stand level aesthetic values will also rise due to a reduced level of management intensity (Booth et al., 1993).

In the western region of NA and parts of Europe, the steep topography, which is characteristic of the region, makes the management for scenic impacts critical. With the emphasis on a variable retention silvicultural system, new guidelines will have to developed for the protection of scenic quality. It is entirely possible that principles of ecosystem management could conflict with some visual objectives. This is particularly true when large organic debris is left on cutover areas and timber harvesting is spread over a much greater area. However preliminary research suggests that the visual quality could be retained in most areas.

In the southern US region, the aesthetic quality could also increase due to variation in forest types, longer rotation ages, less clearcutting, and fewer plantations.

4.4 Summary of Analysis Using Indicators

For all the regions examined there is a lack of quantitative data for all indicators, especially biological and social. The economic indicators used are mainly concerned with shift in the financial implications of changes in the commercial timber supply. To truly provide a more comprehensive assessment, the economic indicators would have to be expanded and include impacts on tourism/recreation, wildlife, and in an ideal situation, many non-use values. Therefore our analysis is largely qualitative in nature, but this does not diminish the validity of our findings. We found extensive discussions on the types of changes that could be expected and presented some preliminary quantitative estimates for some regions. Using this information we completed an assessment which is summarised in Table 3.9.

TABLE 3.9. SUMMARY OF THE DIRECTION OF CHANGES FOR NORTH AMERICAN REGIONS.

Indicator	West	South	North	East
Economic				
Silvicultural treatment costs	-	- 0 +	-	-
Harvest costs	+ +	+	+	+
Access costs	+	0	+	+
Volume of growing stock	0	0 +	+	0
Harvest volume and AAC	--	-	- 0 +	-
Area of exploitable forest land	-	-	- 0 +	+
Area clear-cut	--	-	-	--
Wood value	+	+	+	+
Ecological				
Biodiversity	+ +	+ +	+ +	+ +
Soil condition	+ +	+	+ +	+ +
Soil-water regime	+ +	+ +	+	+ +
Water quality	+ +	+	+	+
Carbon storage	+	+	+	+
Social				
Employment	+	+	+	+
Job skill requirements	+ +	0	+	+
Worker safety	+	-	+	+
Diversity of products	+	+	+	+ +
Indigenous people participation	+ +	0	+ +	0
Non-indigenous people participation	+ +	+	+ +	+ +
Recreation/tourism opportunities	+	+	+	+ +
Visual aesthetics	+	+	+	+ +

In general with the application of ecosystem management the ecological and social indicators demonstrate that in virtually all regions we could move in a more sustainable directions. These improvements appear to exact a financial cost which is shown by the unfavourable direction of most economic indicators. This is to be expected, since sustainability is a complex concept, which the balancing of traditional economic indicators with ecological and social indicators. The move towards ecosystem management leads to a shifting of the balance away from narrowly defined financial considerations towards a more holistic view of the world.

5.0 Conclusions

There have been very few studies done to estimate the impacts on fibre production of the shift from sustained yield timber management to ecosystem management in the world's northern boreal and temperate forests. In our review of the literature, we found general agreement among researchers and practitioners on the direction forest management is going as a result of adopting ecosystem based management practises. This reports summarises our findings by first describing each of the major forest regions and then making a preliminary assessment using economic, social and ecological indicators. Despite the lack of information we feel there are some important conclusions to be made. They are:

- The traditional focus of professional foresters on the sustainability of the timber supply is no longer appropriate for sustaining forests. In order to take a new approach we need new tools and a broadening of principles considered in forest management. For example, new information technology is now available to help with addressing several of the issues raised under the discussion of ecological indicators.

- Ecosystem management is becoming more widespread, albeit it is occurring at different rates in different regions and also at different times. This form of management will be profoundly affected by several areas of public policies including trade, timber pricing, taxation and environmental regulations. To examine various initiatives in public policies, the economic, social and environmental indicators developed and used in this report are useful analytical guideposts in public policy analysis.

- Ecosystem management will restructure timber economies, particularly in terms of timber harvest costs, volume harvested and wood quality. A critical aspect of this restructuring is the rate of change that government, private landholders and companies can accept and still remain viable. On the one hand there are those who argue that the changes must be immediate since we have loss a great deal of critical forest and wildland habitat and have already endangered many life forms. On the other hand, the moderates would argue that the change must be gradually since the social and economic impacts are so pronounced that a gradual approach would facilitate the restructuring that needs to occur without causing significant negative impacts on people who rely heavily on resource extraction activities for a livelihood.

- A shift towards ecosystem management will improve the ecological and social sustainabilty of forest operations which will come at the expense of narrowly defined economic indicator values. The implications of this shift are not fully understood but it is the authors' opinion that with ecosystem management we are moving in a direction which is more sustainable.

- Land use planning and ecosystem management are closely intertwined. The philosophical debate over the best means to implement ecosystem management is still in the infancy stage.

- Land ownership has a profound impact on management practise. For example, currently the intensive forest management system is found almost exclusively on private lands. Most public lands continue to be managed for multiple uses where there are population centres and extensive management where there is low or no human habitation.

6.0 Recommendations

In researching and writing this report we faced several significant challenges, particularly with regards to the integrity of the data. In order to improve upon future reporting we recommend the following:

- Conduct more in-depth case studies.

In order to move to a more quantitative assessment of ecosystem management impacts more measurements in operational settings need to be taken. This requires several case studies since the effects of management will vary widely from region to region. Later, it will also be necessary to conduct representative assessments within each region to address other variations in impacts.

- Include the remaining boreal/temperate forests regions.

It was simply not possible in this project to assess the boreal forests in countries such as India and China. However, new data is rapidly becoming available and this should be integrated to complete the assessment of the sustainable paper cycle. Additionally, new information is rapidly becoming available for the former USSR.

- Re-examine timber supply assumptions.

A more careful examination of some assumptions made about future wood supplies is also warranted. The economic wood supply, as opposed to the biophysical wood supply, is not defined in most regions and appropriate reduction to the total growing stock should be applied. In addition, ecosystem management means a reduction in wood quality for a considerable period of time and this will redefine the economic wood supply. Finally, the sustainability of timber volume coming from forest plantations is debatable which implies that our timber supply assumptions may be incorrect.

- Determine the social and economic restructuring implications of adopting ecosystem management practises.

Ecosystem management practises requires economic restructuring in many rural areas and in the timber companies themselves. Those charged with implementing this form of management should be careful to introduce change at a rate which allows communities and companies to adapt.

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Appendix 1. Case Study of Ecosystem Management Efforts in Europe

A.1.1 Location and Extent of Forests

Located in Central Europe, two thirds of Austria's total land area is within the Eastern Alps. This area is characterised by a subcontinental climate where maximum rainfall typically falls in summer. Altitude, slope, and aspect, which also affect climate, topography and geology, are the dominant factor in the classification of forests. The result is an enormous variety of highly different forest ecosystems.

Some 46.2% of Austria's land area (3.878 million ha) is covered by forest, which corresponds to 0.5 ha per inhabitant (BMLF, 1995b). Exploitable forest accounts for 79% of total forest area, and it has been increasing by 2,000 ha annually since the 1980s (BMLF, 1994).

Austria's forests are not evenly distributed over the federal territory. Mountain slopes in alpine areas and highlands are most densely covered by forests. Due to agricultural activity, poorly forested areas are to be found in Eastern regions, where summers are warm and dry, as well as in the high mountains where the forest line has been lowered by 300 m as a result of former intensive exploitation of alpine pastures. Therefore the forest line is located in the limestone Alps at 1,700 m and in the Central Alps at 1,900 m above sea level.

A.1.2 Major Forest Types

Austrian forests are situated in the temperate forest zone. 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.

Three major forest zones can be distinguished according to approximate altitudinal zones. Eastern Austria is mainly made up of the *colline and submontane forest zone* which ranges from 200 to 600 m elevation and is characterised by oak and beech forests. Between 600 and 1,500 m, the *montane zone* follows along a succession with pure beech (*Fagus silvatica*) forests in the forestland of the Alps, mixed Norway spruce-fir-beech forests in the peripheral zone of the Alps, Norway spruce-fir forests in the Mid-Alps and pure, natural Norway spruce (*Picea abies*) forests in the Central Alps. Depending on climate, the *subalpine zone* (1,500-2,200 m) is inhabited by lower subalpine Norway spruce forests and upper subalpine larch-cembran pine forests.

In comparison to forests of the Western Alps, forests of the Eastern Alps are characterised by less diverse and complex ecosystems as well as less distinct transitions between them.

TABLE A.1. MAIN FOREST ECOSYSTEMS IN AUSTRIA

Altitude	Key Forest Ecosystem	Additional Species
200 m	Lowland alluvial forests: Poplar/Willow and Mixed deciduous forests	Oak, Ash, Lime, Cherry, Alder, Maple, Hornbeam
200-500 m	Central European mixed Oak-Hornbeam forests	Cherry, Ash, Maple, Lime, Robinia, Chestnut, Beech
500-1.300 m	Mixed Beech-Fir forests Spruce-Fir-Beech forests	Pine, Spruce, Larch, deciduous species
1.300 m	Subalpine Spruce forests Spruce-Larch forests *Pinus cembre* forests	Pinus, Acer, Sorbus

Source: MECCA, 1990.

Economically exploited forests most commonly consist of Norway spruce with a share of 56 % of the forest land area, followed by beech (9 %), various pine species (6 %), larch (*Larix decidua*) (5%) as well as white fir (*Abies alba*) and oak species (BMLF, 1995a).

A.1.3 Past and Present Forest Use

Alpine valleys have been populated since the Stone Age. Although Alpine pastures were already established in the Bronze Age, pressure on forests was greatest in the Middle Ages when permanent settlements were founded up to 2,000 m above sea level due to lack of agricultural land. In the Eastern Alps significant human influence can be traced back 800 years, while in the climatically more favourable Southern and Central Alps this influence can be dated back 4,000 years. As early as the Middle Ages, forest regulations were enacted to maintain forests as a resource to provide raw material and energy for mining, salt and iron manufacturing. In 1852 the Imperial Forest Law was introduced to enforce the concept of sustainability (BMLF, 1995b). Already at that time forests were seen as intensive multiple-use entities, not only as sources of wood fibre.

Due to century-long agricultural exploitation of the Alps, forests were cut up to the border regions of little productivity. Cattle grazing in the forest is a historical problem which persists today. Currently, unfavourable agriculture land has been largely abandoned, leading to the above-cited increase in forest land area.

Today, forest management follows the regulations found in a 1975 Austrian forest law, and amendments made in 1987. It aims at securing the four functions (protection, economic, welfare/social and recreation) of the forest on a sustainable basis (BMLF, 1994). Regarding the importance of these functions, the economic function receives the highest priority (65 % of function of forest land area) followed by the protection function (31 %), as documented in the National forest development plan (BMLF, 1993).

Sixty-one per cent of protection forests are not exploitable and therefore are excluded from any timber harvesting. Local forest authorities define and control the appropriate management, particularly within forest reserves, which focuses purely on the protection of human settlements and infrastructure against avalanches and torrents.

A large number of Austrians earn income or wages directly from the production of wood products. Some 7 % of the Austrian gross national product is generated by the forest sector. Furthermore, Austria is one of the most tourism-oriented countries in the world. With 7.9 million inhabitants, it accommodates 30 million tourists and 120 million overnight stays each year. Therefore, the forest experiences constantly rising use pressure and becomes increasingly important as a source of recreation. For example, there are a total of 6,000 km of ski runs (MECCA, 1990).

Besides their recreational importance, some 0.8 million ha or 22 % of the forest land area serves as protection forests. These are concentrated in western parts of Austria where they prevent soil erosion and forest degradation, and give shelter to human settlements and infrastructure.

Another non-wood benefit is derived from wildlife management, which has led to moderate increases in game stocks. However, wildlife populations extensively damage natural forest regeneration and young forest stands. Each year, some 55,000 ha of forests or 42 % of exposed young trees are browsed and peeled.

A.1.4 Area, Volume, and Projected Harvest Levels

The exploitable forest land area amounts to 3.331 million ha with an average growing stock of 292 m^3/ha and an annual increment of 9.4 m^3/ha. In contrast, the annual harvest averages 5.9 m^3/ha, which adds up to 19.8 million m3

(BMLF, 1995b). This results in an increase of growing stock of 1.2 % annually which could support a significantly higher timber harvesting rate of up to 31.4 million m3. A harvest volume of some 72 million m3 could be made available from only under-utilised thinning reserves. Currently, thinnings contribute 15 % to the annual timber harvest.

Some 214.000 private owners own a total of 80 % of the forest land. Although 92 % of forest owners have holdings of up to 20 ha, they account only for 25 % of the total forest land area. This expresses the fact that forests are mainly owned by farmers who see their forests as a multiple-use resource, especially as a savings account for investments as well as source of raw material and energy.

A.1.5 Sustained-Yield Timber Management

According to Mayer (1984), classical forest management is characterised by a nature-oriented distribution of tree species with long rotation periods (100-120 years), high growing stocks (250-300 m3/ha) and a high intensity of forest operations (pre-commercial and thinning operations make up 40-50 %). Through this kind of intensive age-class forest management, large-dimension timber of high quality and value is produced. Köstler (1967) sees the modern aspect of forest management in the sustainable production philosophy of classical forest management, which, based on century-long experience, ensures an optimisation of natural potentials.

Currently Austria's forest growing stock is increasing and its timber resources are significantly under-utilised. But this information only documents the quantitative sustainability of timber production. Lutschinger (1993) states that a comprehensive understanding of sustainability should also include ecological factors, which contemporary experience has yet to incorporate. Pro Silva Austria (1995) demands a change in the understanding of forest sustainability from continuous timber supply to maintaining the production potential of forests.

A.1.6 Ecosystem Management Through Nature-Oriented Forest Management

The demands made by the population on the forests are high, particularly because of their various functions. Partly this fact is in accordance with the concept of multiple use of Austrian forests. As new impacts such as tourism or forest decline cannot fully be solved by this century-old concept, instruments have been introduced to co-ordinate and secure the multiple use of forests, including the National Environmental Plan, the Austrian forest development plan, the danger zone map, the Austrian natural forest reserve network, and the 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. These are forest decline, ecologically unfavourable land use methods such as high deer, stag and chamois populations, insufficient forest management, cattle grazing and decreasing stability and yield due to historical exploitation of forests, the change in land use such as recreation and tourism, fuelwood plantations and waste disposal, the construction of forest roads. The NEP lists measures necessary to provide sustainable forest use.

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 optimum, sustainable maintenance of the functions of the forest. It is used for political decision- making with respect to both federal and provincial forests. All the forest land area is inventoried, assessed for values, and mapped. The forest is divided into 17,000 areas to which a primary function is assigned from one of the four forest function types mentioned above. 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.

For example, the forest development plan identifies areas, mainly located in sparsely wooded areas, for forest restoration in the public interest. Such activities are the politically appreciated reforestation at high altitudes as a compensation for historically cutting back of the altitudinal forest line, the restoration of some 0.5 million ha of cleared forest land which are currently used for cattle grazing, and the elimination of cattle grazing from forests. Regarding reforestation at high altitudes, some 161,000 ha or 21% of protection forests is estimated to require urgent restoration and regeneration (BMLF, 1993).

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 preserving biological variety and permitting research and teaching. So far, it includes some 3,000 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 at preserving the genetic resources of forest tree populations by selecting and taking care of gene reserves, long-term storage of forest seeds, and installation of seed plantations. As a precondition for their adaptation to future conditions, particular consideration is given to adapted alpine forms and rare indigenous tree species.

A.1.6.1 New Trends in Forest Management

A long-lasting theory, the so-called "Kielwassertheorie" or "wake theory", suggests that competing interests in forests such as the forest functions are fulfilled by the economic function which is timber production (Glück and Pleschberger, 1982). By putting biased emphasis on the economic use of forests, forest management has favoured profitable coniferous tree species and *the use of economically efficient methods such as clearcuts. This has resulted in* an increased representation of conifers, mainly due to widespread planting of spruce and pine. In order to overcome the resultant ecological drawbacks, Austrian forest policy makes every effort to enforce nature-oriented reforestation through ecologically adapted silviculture. The share of deciduous and mixed forest stands now amounts to 42%, a 27% increase since the 1970s. While artificial regeneration only occurs on 2% of the total forest land area, natural regeneration already covers 15% but contributes 87% to all forest regeneration (BMLF, 1994).

In order to realise this regeneration potential, more than half of final felling operations are regeneration cuts, clearing of old stands and small-sized fellings. In particular, single-stem harvest operations have shown an 8% increase during the last decade, while the area resulting from clearcuts decreased by 20%. Still, clearcutting accounts for a 47% of 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 the reason why clearcuttings result in a diverse mosaic of even-aged patches of forest stands.

In 1993 an initiative under the leadership of the World Wide Fund for Nature Austria (WWF, 1993) aimed at changing the assignment of the Austrian federal forests from purely economic to economic and ecological benefits. According the WWF, public forests should be managed to provide a wide range of social benefits.

Recently a national expert team has defined a general set of criteria for sustainable forest management. Currently this set of criteria is subject to field testing according to the procedure set out by the Center for International Forestry Research with the aim of defining a final list of practical indicators.

Another recent forest valuation concept is based on an ecopoint model. It takes the potential natural forest vegetation into account when human influence is excluded (Maier, 1995). It is guided by the prevailing understanding among forest experts that uneven-aged and mixed forests have a higher ecological value than monocultural forests. Thereby, ecopoints are assigned to the forest's tree species composition, the structure and texture, the share of natural regeneration as well as structural features such as small biotopes, old-growth stands, dead trees or rare tree and shrub species. This model is currently under testing, but it is designed to restructure forests with the help of ecopoint-related subsidies.

By signing the convention on biodiversity at the United Nations Conference for Environment and Development in 1992, and the resolution of the ministerial conference for the protection of European forests in Helsinki 1993, Austria committed itself to set up a network of forest reserves. Relevant institutions have initiated a working group on natural forest preserves in the Vienna woods which aims at identifying natural forest preserves. A list of recommendations and criteria is expected to stimulate the establishment of forest preserves in which scientific research is the only permitted human activity (WWF, 1995).

A.1.6.2 New Forest Management

The ongoing discussion on "Naturnahe Forstwirtschaft", a synonym for nature-oriented forest management, considers the fact that Austria's forests are a cultivated landscape resulting from centuries of human care and attention. Similar to virgin forests, intensively multiple-used forests are rich in terms of biodiversity too and therefore subject to maintenance as demanded by law.

The question has been put forward how nature-oriented forest management would differ from traditional sustainable forestry. According to Pro Silva Austria (1995), a regional association of nature-oriented forest experts in Europe propagating a more holistic view of the nature of the forest ecosystem, the system of age-class forest management has to be replaced by their widely recognised principles in order to achieve ecological and economical sustainability:

No clear cutting, spatial forest order and rotation period;
Balance in increment and harvest;
Regular timber harvests of low yield;
Tending and harvesting decisions made on the basis of individual stem characteristics.

Economic sustainability is based on ecological sustainability which follows selecting tree species according the potential natural forest association; maintaining and promoting admixed rare or endangered tree species; securing soil productivity by maintaining a protective forest canopy; keeping forest residues and dead trees in forest stands; preserving the typical climate of forest stands, and their specific flora, fauna, and biodiversity. Pro Silva Austria advocates 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). Thereby, single-stem treatment goes far beyond the stand-level approach to ecosystem management.

So far, the strategy of linking international and regional aspects of sustainable forest management has been realised by meeting the principles and criteria of the Forest Stewardship Council (1995). In addition to Pro Silva's principles, the WWF demands that 10% of the total forest land area be set aside in natural forest preserves. These areas should be withdrawn from any exploitation, which is seen as the most promising means of preserving biodiversity.

Due to its high profile on the political agenda, the discussion is stimulated by non-forest related environmental groups, forestry lobbies, forestry companies and forest authorities which mainly co-ordinate this process. What do they demand? While environmentalists emphasise ecological sustainability and the establishment of forest areas where human influence should be forbidden, forestry lobby groups, particularly small-scale forest owners, advocate retaining the philosophy of sustainable multiple-use forest management as an elementary part of Austrian culture. That is why the discussion follows ecolabelling of timber and related products rather than of forest companies and forest land. Individual forest companies seem to be much more responsive to undertaking ecosystem management, particularly with the prospect of ecolabelling and the likely competitive advantages resulting from achieving it.

Small-scale forest owners depend much more on the multiple-use of their forests, so their lobbies try to avoid binding regulations taking major forest preserves into account. Furthermore, they demand that nature-oriented forest management should be executed voluntarily and supported by the use of publicly-funded incentives and subsidies. For example, they argue that the protection of remaining virgin forests should be the responsibility of forest owners, since officially designated areas may attract excessive public interest and thereby harmful influences. This concept has been applied in the newly established national park Hohe Tauern located in the heart of the Alps. The local population is expected to use the forests privately in the traditional way and thereby maintain socio-economic structures of naturally, historically and culturally created biodiversity.