The Alberta GPI Accounts: Forests

Report #20

by

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Pembina Institute
for Appropriate Development

About the Pembina Institute

The Pembina Institute is an independent, citizen-based organization involved in environmental education, research, public policy development and corporate environmental management services. Its mandate is to research, develop, and promote policies and programs that lead to environmental protection, resource conservation, and environmentally sound and sustainable resource management. Incorporated in 1985, the Institute's main office is in Drayton Valley, Alberta with additional offices in Calgary and Ottawa, and research associates in Edmonton, Toronto, Saskatoon, Vancouver and other locations across Canada. The Institute's mission is to implement holistic and practical solutions for a sustainable world.

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About this Report

This is one of 28 reports that provide background for the Genuine Progress Indicators (GPI) System of Sustainable Well-being Accounts. See Appendix A for a full list of reports. Research was completed early in 2001.

This report examines the trends in the sustainability and ecological health of Alberta's forests as a measure of the genuine well-being of Alberta's natural capital and ecosystem integrity. The report represents the continued development of forest resource accounts for Alberta that were initiated by Mark Anielski (formerly of Alberta Forestry, Lands and Wildlife, and Alberta Environment) to provide a meaningful accounting system that tracks the sustainability of forest capital. This report looks at several trends in some key indicators of both the biophysical condition of Alberta's forests as well as the economic returns to Albertans from developing forest and timber capital resources. Indicators such as the Timber Sustainability Index (TSI) are derived from detailed forest resource accounts that compare annual growth rates of timber with the annual depletion rates due to harvesting and natural disturbances by fire, insect and disease. This report also examines the condition of forest ecosystems by looking at the trends in the fragmentation of these ecosystems due to industrial development and linear disturbance. We also examine other forest ecosystem services including carbon sequestration and watershed services. Finally, the report examines the economic returns to consuming timber capital that contribute to Alberta's economic growth and prosperity; indicators such as forestry GDP, forest economic rent and jobs per unit of wood harvested. The report provides a forty-year picture of the sustainability of the living capital of Alberta's forest and asks the questions: are Alberta's forests sustainable over the long term and are there emerging risks to sustained timber harvest due to fire and other liabilities?

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Acknowledgements and Disclaimer

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The high quality of data compiled by the Alberta Forest Service and Statistics Canada enabled us to undertake a much more thorough construction of forest resource accounts that would otherwise have been possible. We also thank Kim Sanderson for her editing assistance. Finally, the Pembina Institute appreciates the vision of Western Economic Diversification in supporting this project—the first of its kind for Alberta, if not internationally.

The contents of this report are the responsibility of the Pembina Institute and do not necessarily reflect the views and opinions of those who are acknowledged above or the opinions or positions of Western Economic Diversification who helped fund the research.

We have made every effort to ensure the accuracy of the information contained in this document at the time of writing. However, the authors advise that they cannot guarantee that the information provided is complete or accurate and that any person relying on this publication does so at their own risk. Given the broad scope of the project and time constraints, it has not been possible to submit the entire report for peer review. The material should thus be viewed as preliminary and we welcome suggestions for improvements that can be incorporated in any later edition of the work.

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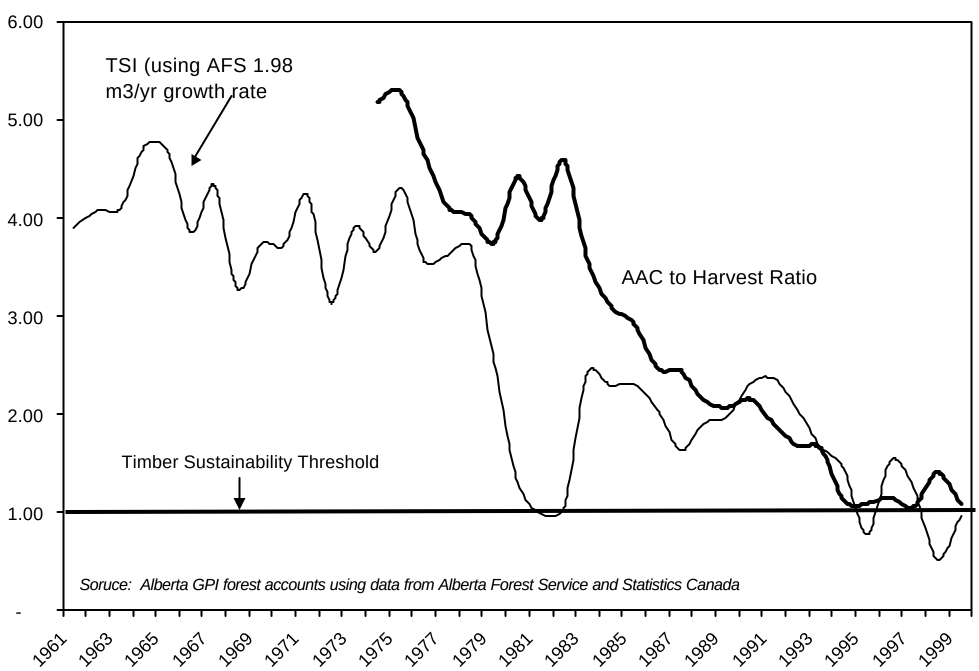
1.1 Timber Sustainability in Alberta: How Much?

Forests cover about 58 percent of Alberta's 66.2-million hectare land base. Roughly 17.8 million hectares are suitable for industrial timber harvesting. Are Alberta's forests sustainable? Two indicators, the Timber Sustainability Index (TSI) and the Annual Allowable Cut (ACC) reveal different stories (see figure below). Using detailed forest resource accounting methods, we estimated a TSI, which is the ratio of annual growth of timber capital to total timber depletions from harvesting, fire, industrial land use and insects. The TSI shows that in the late 1990s, total depletions exceeded annual growth of timber capital, implying unsustainable timber consumption. In contrast, the 1999 timber harvest was roughly 93 percent of the AAC—the amount of timber that professional foresters determine is harvestable on a sustained yield basis. Thus, while the TSI indicates that current rates of forest harvesting exceed sustainable levels, the AAC says harvesting rates are within sustainable levels. The risk to exceeding the AAC increases with natural catastrophes (fire, insects), oil and gas development and timber harvest demands. Looking beyond simple timber capital, we also account for the integrity of forest ecosystems by assessing the degree of fragmentation due to dramatic increases in oil and gas development across the province. By 1999, roughly nine percent of Alberta's "productive" forests were estimated to be in an unfragmented condition.

Noteworthy

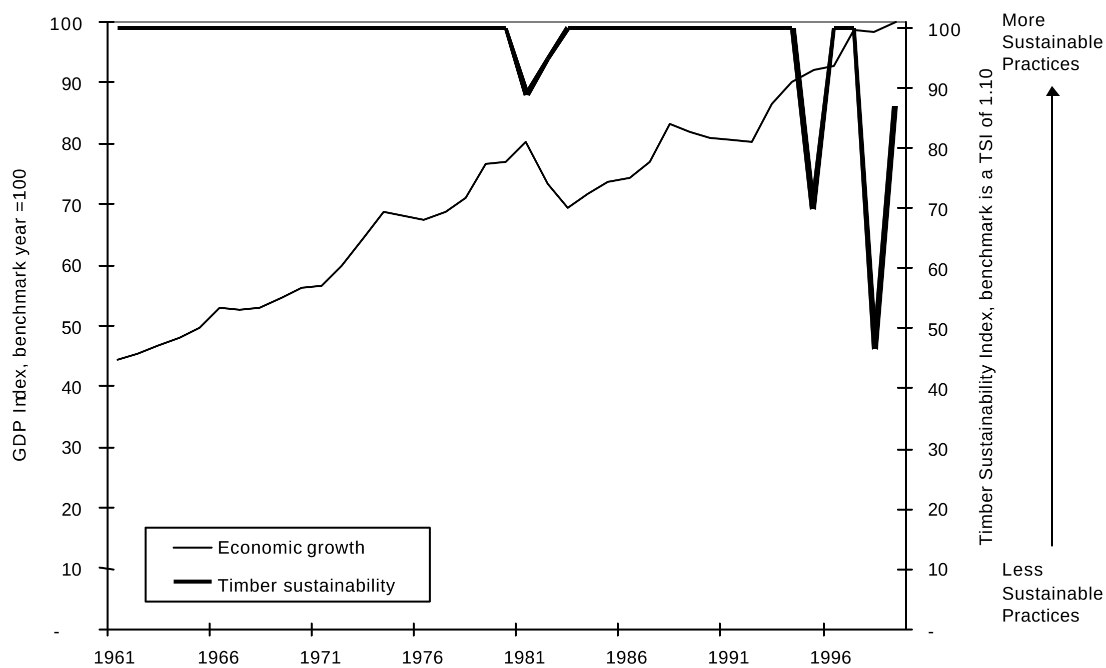
- Since 1961, the volume of timber harvested has increased by 586%—to 23.0 million cubic metres in 1999.
- Based on our estimated Timber Sustainability Index, Alberta went from a "surplus" of 4.7 in 1964 to a timber sustainability " deficit" of 0.87 by 1999. In other words, more timber is being liquidated than is being replenished through natural growth and regeneration.
- The volume of timber harvested in relation to the Annual Allowable Cut (AAC) has gone from 19.3% in 1974 to as high as 95.0% in 1997; thus the limit of allowable cut as defined by the Alberta Government is virtually maximized.
- If current harvesting, fire, and linear disturbance (oil, gas, roads, and other developments) continue, Alberta's oldest trees—so-called " overmature timber"—will be gone in roughly 42 years and will have been converted to an industrial forest where timber capital is managed on a just-in-time inventory basis.

Alberta Timber Sustainability Index (TSI) vs. Annual Allowable Cut (AAC) to Harvest Ratio, 1961 to 1999



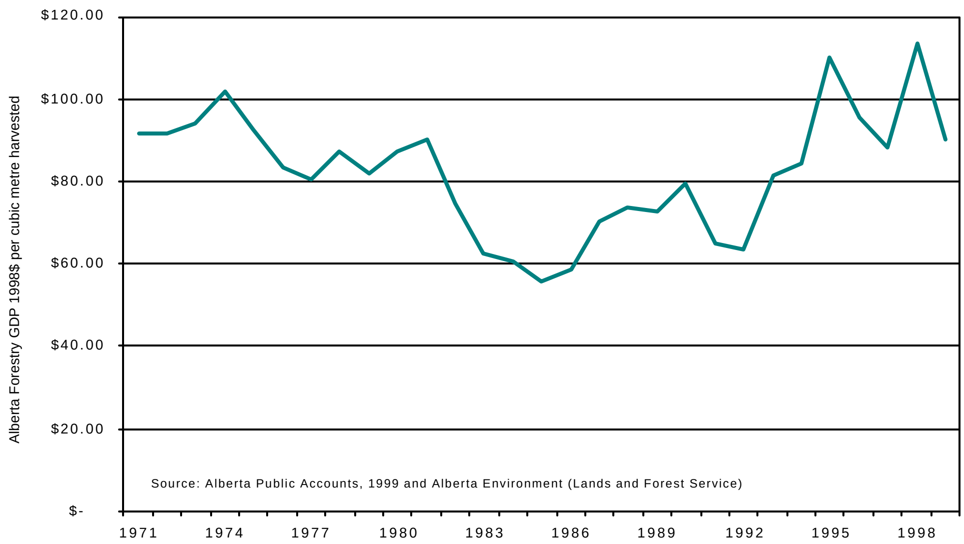
Sustainable stewardship of renewable resources means living off the interest of nature without eating into the capital stock. The GPI forest accounts show that both timber capital sustainability and forest ecosystem integrity (due to fragmentation) have been declining. While exceeding timber capital sustainability may not be of immediate concern to the forest industry—which can adapt to changing market demands and resource scarcity—there is a more fundamental question about the long-term ecological and economic impacts of loss of ecosystem integrity. Forests are complex systems that provide many benefits and services. Our timber accounts show that Alberta appears to be living beyond the interest of nature's capital when the cumulative effects of harvesting, industrial development and natural impacts are considered. These conditions and trends may not be problematic for industrial foresters whose goal may be to move towards an even-aged forest management regime. However, to some ecologists the fragmentation of the forest, loss of species diversity and effective wildlife habitat as well as the liquidation of old-growth ("overmature") trees is seen as a real threat to ecological health. Our Timber Sustainability Index (TSI) shows that timber sustainability was breached in 1981-82, 1995 and then 1998-99 even as the GDP continued to increase (see the figure below).

Timber Sustainability Index: Where are we today?



Despite expansion of Alberta's forest industry, economic returns in terms of forest industry GDP per tree harvested, have remained virtually unchanged over 30 years of development (see figure below). Moreover, direct employment per cubic metre of timber harvested has actually declined from 2.4 jobs per 1,000 cubic metres harvested in 1967 to just 0.84 jobs per 1,000 cubic metres in 1999. While putting a price tag on the cost of unsustainable timber consumption is difficult, we estimate: a) cost of non-timber values due to loss of productive forest land to be $23.8-million in 1999, and b) the cost of unsustainable timber capital depletion in terms of pulp production values at $14.6-million in 1999. Thus, the total cost was an estimated $38.4-million in 1999.

Alberta Forestry GDP per Cubic Metre of Wood Harvested, 1971 to 1999 (1998$)



1.2 Forest Fragmentation in Alberta: The condition of forest ecosystems

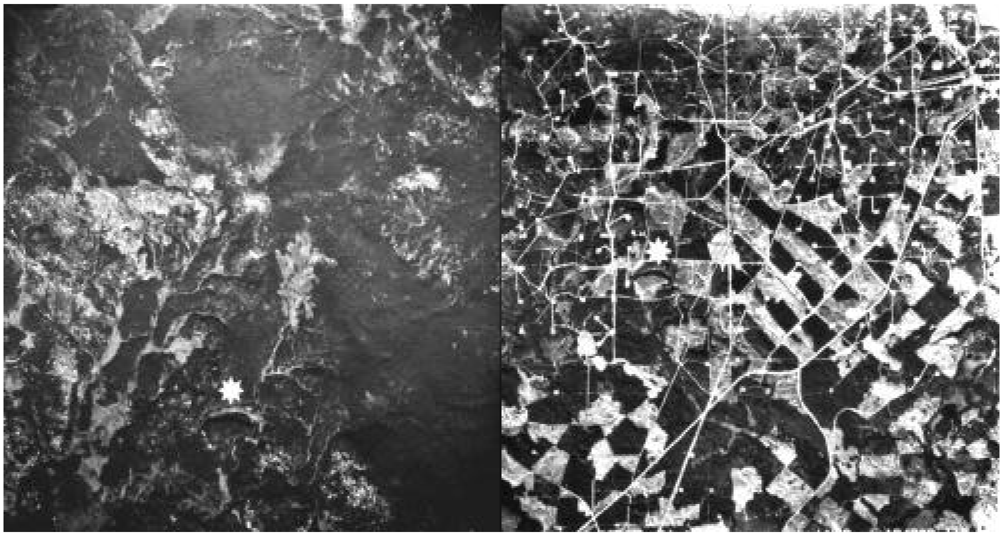
Alberta's forests are highly fragmented due to the impacts of timber harvesting, roads, wellsites, seismic lines, pipelines, powerlines, and other forms of linear disturbance. Based on the Alberta GPI forest resource accounts, as of 1999, over 90 percent of Alberta's productive forest was fragmented. The extent of forest fragmentation can best be illustrated in aerial photographs. The images below show the same area of the Swan Hills forest in 1949 and 1991. Up until 1999, the total area affected by energy and other industrial development in Alberta's Green Area (forest) was estimated at 1,482,430 hectares—an area almost half the size of Vancouver Island.

A 1998 study for Alberta Environmental Protection found that the ecological integrity of Alberta's boreal forest ecosystem (the majority of the province's forest land) had been moderately to seriously compromised, with only 12.8 percent of the area without roads, and 14 percent remaining as viable core wildlife habitat. A previous study found that in Alberta's Foothills forest region, linear disturbance had left less than 1% of the forest unfragmented. Both studies concluded that cumulative impacts of human activity threatened long-term biodiversity. This fragmentation is illustrated below.

Noteworthy

- The cumulative impact of human activity (agriculture, oil and gas exploration, forestry, settlement, roads, oilsands mining, power lines and other activities) has resulted in an ecological footprint so large that less than 9% of townships in the Boreal forests and 1% in the Foothills forest remain intact as wilderness (unfragmented).
- Up until 1999, the total Green Area (forest) affected by industrial and agricultural development was estimated at 1,482,430 hectares—roughly 115% of the total forest area havested between 1961 and 1999.
- A 1998 report for Alberta Environmental Protection, *The Boreal Forest Natural Region in Alberta,* found that only 23.4% of the boreal forest portion of Alberta's Green Area is not allocated to Forest Management Agreements.
- The rate of deforestation (1949-1995) in Alberta's southern Dry Mixedwood forests was found in one study to be proportionately higher than the annual rate of deforestation for the Amazon rain forest (1975-1988).
- Agriculture development is responsible for the largest area of wildlife habitat loss while oil and gas development has caused most of the habitat fragmentation.

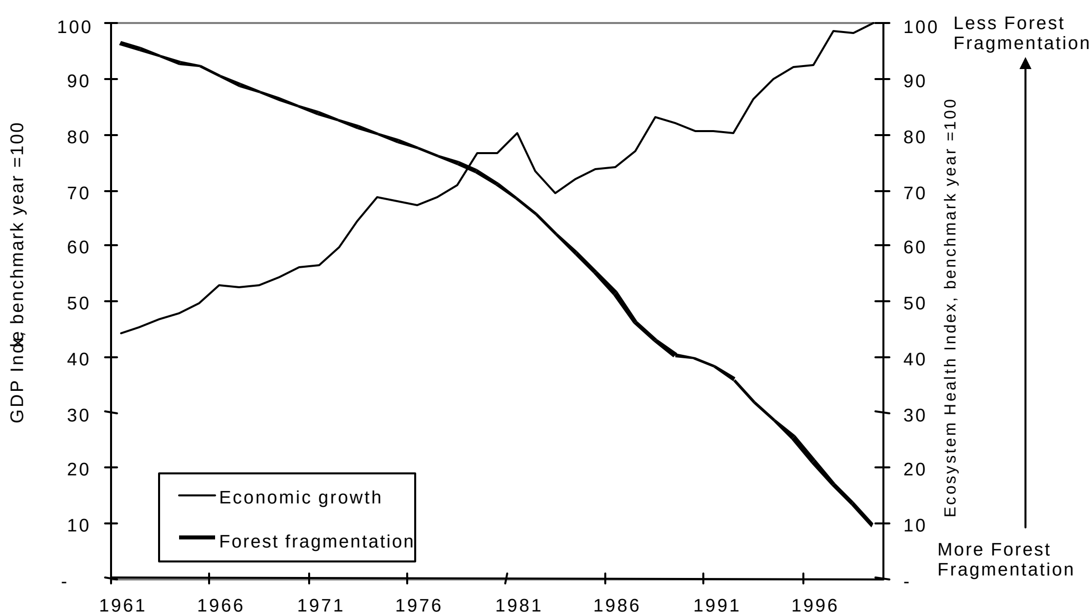
Alberta's Swan Hills Forest Ecosystem, 1949 (left) and 1991 (right)



Whether visual or numeric, measures of integrity of forest ecosystems tell us a great deal about our stewardship of the environment.

The visual and empirical evidence of fragmentation and loss of integrity of forest ecosystems is clear. The figure below shows that as Alberta's GDP has increased since 1961, so too has the amount of forest fragmentation. The forest fragmentation index stood at a mere 9.5 in 1999 on a scale of 0 to 100, where 100 represents optimum ecological integrity for the period 1961 to 1999. Satellite or aerial imagery of Alberta would reveal a "spider web" of linear disturbance that cuts up the provincial land base. Should we be concerned? The real, long-term impacts on ecological health, wildlife, climate and human health are as yet unknown. Understanding why forest ecosystem integrity matters to the well-being of present and future Albertans and to nature is a challenge. At the very least, Albertans should be shown the visual costs of developing these resources and exporting mostly non-renewable natural capital over the last 30 years.

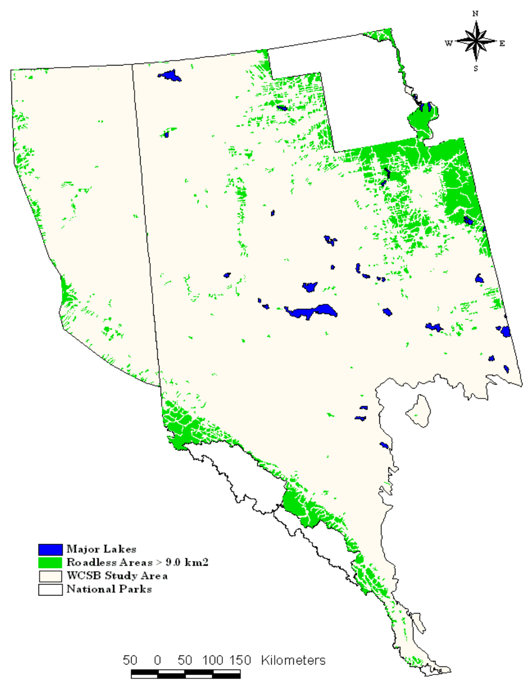
Forest Fragmentation Index: Where are we today?



The full ecological costs of these impacts are just beginning to be evaluated. In the meantime, more pipelines, wellsites, seismic lines and other corridors are being constructed to give access to smaller pools of natural gas and enable Alberta's natural capital to be exported. With demand for natural gas growing and oilsands development expanding, no corner of Alberta outside of designated parks will be left untouched by development (see figure below). Ultimately, Albertans must decide if the benefits of an additional barrel of oil or cubic metre of gas exports outweigh the uncertain costs of loss of ecological integrity. Sustainable stewardship of natural capital requires careful management of all values, ensuring the maintenance of ecosystem health, diversity and resiliency.

Putting a price tag on the cost of loss of forest ecosystem integrity due to fragmentation is beyond the scope of this study. However, some researchers have begun to estimate the non-market values from the loss of ecosystem services, which might be considered in future GPI estimates.

Remaining areas with access densities greater than 9.0 km^2 in the forests of Alberta and northeastern British Columbia, 1997



The figure to the left shows a satellite image of Alberta in 1997. The blue (dark) areas are major lakes and the green (gray) areas are roadless areas of more than 9 km^2, excluding parks (white).

World Resources Institute

2. Introduction

Sustainability means living off the interest of nature's capital. To sustain forest capital means living within the carrying capacity of the forest ecosystem to sustain a flow of goods and services without a loss in material quality—that is, sustaining the integrity of all forest values, including timber and non-timber capital. GPI accounting for the living capital of forests entails constructing total forest capital accounts that show the long-term conditions of the forest ecosystem as well as the monetary value of benefits in terms of goods and services derived from the forest for consumption or non-consumptive use. These GPI accounts examine both the depletion and regenerative rate of timber capital (i.e., trees consumed for commercial value) as well as the integrity of forest ecosystems for sustained ecological services.

Forest ecosystems provide a variety of timber and non-timber products and ecosystem services, including construction material, paper products, fuelwood, drinking and irrigation water, and fodder. Forests also provide recreation, genetic resources, and aesthetic beauty. They remove air pollutants and emit oxygen, sequester carbon, moderate weather impacts, cycle nutrients, provide human and wildlife habitat, generate soil, and maintain watershed functions and biodiversity. Throughout this paper we define these goods and services provided by forest ecosystems as "forest capital" or "forest wealth."[a] Many of the goods and services provided by forest ecosystems and values go unnoticed in economic accounts of nations, implying they are "free," at least in terms of monetary value. Conventional economic accounting measures the value of forests primarily in terms of the market value of timber harvested. As we harvest more timber, measured income rises, giving us the illusion of limitless growth even if we are eroding the living capital assets of the forest. The GPI Accounts begin to expand the perspective by accounting for the condition and sustainability of all forest ecosystem values, both in physical and qualitative terms and in terms of their full monetary benefits and costs.

How should we account for the sustainability of goods and services provided by complex forest ecosystems in our money-based economic accounting system? Defining and measuring sustainability of a complex system such as a forest is a complicated matter. What constitutes ecological integrity and how should we measure it? With different values held by society on how forests should be managed and to what ends, there is no accounting stance or indicator of forest well-being that will satisfy all parties who benefit from the forest. Common sense suggests that we must first account for the current state of all forest ecosystem resources and values, expressed in physical terms (stocks and flows) and in terms of ecosystem services and monetary values (benefits and costs) for both market (timber) and non-market (non-timber) values as an integrated system. We also need historical accounts of how forest capital conditions have changed over time as a result of human impacts (e.g., harvesting, linear disturbance) and natural disturbance (e.g., fire, insects).

Second, we must examine the risks and threats to sustained values and services from forest ecosystems. These risk profiles will vary according to different values held by society. The progressive liquidation of old-growth ("overmature") timber may matter little to a flexible, adaptive forest industry that will adopt new standards, processes and products to make use of younger and smaller trees. However, citizens might be concerned with the loss of old-growth forests and valuable large trees, and forest wildlife and ecosystem services might suffer as a result of a less bio-diverse forest.

[a] Wealth, in fact, means " the condition of well-being" in the Old English (see Webster's New World Dictionary).

Third, we can examine the full benefits and costs of using timber to make forest products and exports, and compare them with the value of forest ecosystem services and non-timber resources in a way that recognizes both market and non-market values. In other words, the total value of forests must be accounted for in assessing their contribution to the well-being of Albertans. This is the essence of GPI Accounting—holistic value accounting for sustainability.

The Alberta GPI Forest accounts are a work-in-progress using the best available data at our disposal (see Appendix B for data information). Despite more than ten years of work to develop forest accounts that provide a definitive picture of forest sustainability in Alberta, significant data and information gaps remain. We have attempted to use the evidence revealed by interpreting raw data or indicators—compositions of raw data that give important insights about sustainability. We sought to strike a balance between the timber-supply focus of industry and an environmental protection perspective, accepting that a range of values will always exist and that consensus on the right mix of values and management practices will require ongoing dialogue and compromises. We recognize that, to some, our interpretation of the data may seem biased and pessimistic, while to others it may seem optimistic. This is the nature of discussions about sustainable development of value-laden issues like environment and forests.

Our approach recognizes the inherent shortcomings of the data and the uncertainty in defining and measuring sustainability on a provincial scale. There are no "black and white" answers; rather there are many gray areas. We acknowledge the need for continuing research and analysis to provide a more informed picture of forest sustainability. This will require a mature and open dialogue among all parties—industry foresters, government foresters, academics, environmentalists, citizens, Aboriginal people and political leaders. We have tried to present the data without bias and leave interpretation of the trends to the reader, and we stand accountable for our positions and interpretations.

We acknowledge, for example, that the long-term, ecological impacts of continued fragmentation of forest ecosystems due to seismic, energy and other linear disturbances are uncertain. Nevertheless, such fragmentation continues and will increase as oil and gas developments ramp up in the years ahead. In the long term, fragmented forests will likely heal themselves in spite of our best management efforts. With respect to carbon, there is uncertainty about whether forests are net sources or net sinks of carbon. While forests act as massive sinks of carbon and sequester carbon annually, we are still unclear whether forests can absorb excess amounts of carbon emitted by households and industry and how other natural impacts (e.g., fire) fit into the carbon budget equation. The evidence from timber inventories suggests that "overmature" timber (old growth) is gradually disappearing. When the cumulative impacts of harvesting, fire, insects, and oil, gas and agriculture development are considered, these "overmature" timber age classes on productive, public forest land will eventually be gone. To most professional foresters, this comes as no surprise with the fulfillment of a policy of harvesting the oldest timber first and moving to a younger, even-aged forest inventory stand; to others, this trend of losing Alberta's old-growth forest may be disturbing.

Depending on your perspective or scale of analysis (macro or on-the-forest floor), the assessment of sustainability will vary. As a forester working on the ground, you might see some of the good things that are happening—like reforestation success and new forest management practices to address some of the longstanding concerns about clearcutting and its impact on wildlife and ecosystem services. Moving to a just-in-time inventory of mature trees[b] may be a desired

[b] A "just-in-time inventory" would mean a 70-year cycle for deciduous hardwoods and 100 years for coniferous softwoods.

outcome for professional foresters but it may differ from the values of some citizens for an ecologically diverse forest. We acknowledge the successes and progress of many forest companies in moving to a less fibre-intensive forest management regime, as we learn from nature and from our desire to "manage" forests for economic and financial returns. Forest management is an iterative learning experience, requiring flexibility and ongoing calibration.

Measuring forest sustainability is complex and beyond a single indicator. Our own Timber Sustainability Index, or TSI,[c] provides a narrow view of sustainability by focusing only on timber supply. However, combining the TSI with indicators of forest fragmentation, as a proxy for forest ecosystem health, and with indicators of age-class diversity, we begin to create a more complete picture of forest conditions that relate to both economic and ecological sustainability. While we need to examine the forest from a timber "supply side," we must also examine the "demand side" without losing an ecological perspective on forest ecosystem health. And we must account for the permanent loss of the value of "overmature" trees that will result from our harvest-at-maturity timber supply practices, including the market and non-market value of large spruce, pine or aspen trees. The GPI accounts attempt to consider a broad spectrum of ecosystem health and timber sustainability indicators, based on best available evidence and in recognition that we may have missed some emerging scientific evidence that could refute our observations.

Some of the constraints to achieving long-term forest sustainability in Alberta may not be entirely timber supply issues but may require greater flexibility from government policies for resource allocation. This points to the need for flexibility in the face of continued uncertainty, particularly uncertainty related to natural disturbance and climate change. For example, as timber supply constraints do emerge, as is likely with the cumulative impact of fires, insect and land use losses to oil and gas development, more flexibility will be needed in assigning timber property rights.

We know that Alberta's forests will survive in one form or another beyond our generation. However, the forests we leave to our grandchildren most certainly will differ from those we inherited. The question remains, what kind of forest legacy do we want to leave future Albertans given the evidence presented in these accounts about the current conditions and health of our forests?

[c] The TSI is the ratio of timber growth to depletions.

3. Noteworthy Changes in Alberta Forest Conditions

The condition of Alberta's forest capital over the 38 years of the Alberta GPI accounts (1961 to 1999) shows a decline.[d] These conditions vary according to the particular parameter used to measure forest capital conditions, but some noteworthy indicators of forest ecosystem health and sustainability are given in Table 1 below.

Table 1: Indicators of Forest Ecosystem Health

Forest Ecosystem Condition Indicators	Condition-Trend (1961-1999)
Timber Sustainability Index: long-term sustainability of timber supply	Worse – Declining (down 45%)
Diversity of forest age-classes	Worse – Declining (younger forests; less old growth)
Old-growth ("overmature") timber	Worse – Declining (30% loss of 80+ year age classes since 1991. Old-growth forests on provincial, productive forest land are estimated to be depleted in 42 years.)
Timber harvesting	Increasing (up 586% to 23 million cubic metres)
Forest fragmentation (due to oil, gas, roads, harvesting and agricultural development)	Worse – Increasing (Over 90% of Alberta's non-preserved forests are fragmented; the deforestation and fragmentation rate in Alberta's forests are greater than in the Amazon rainforest)
Loss of keystone forest fish and wildlife species	Worse in some cases (grizzly bear, caribou) and better in others (deer)
Deforestation due to energy and agricultural development	Worse – Increasing (up 315% per annum, a total of 1.36 million hectares—2.4 times the size of Prince Edward Island or roughly 48% the size of Vancouver Island)

Indicator of Forest Economic Health[1]	Condition-Trend (1961-1999)
Real Forestry GDP (1998 constant dollars)	Better – Increasing (up 330%)
Real Forestry GDP per cubic metre of timber harvest (1998 constant dollars)	Worse – Improving (down 2%)
Jobs per cubic metre of timber harvest	Worse – Declining (down 47%)

[d] There are many different perspectives on assessing the overall conditions of forest ecosystems, depending on what values one holds and considers meaningful in presenting such a well-being portrait. The lack of longitudinal data that extend more than 50 years makes it difficult to meaningfully compare the conditions of today's forests with the forests 100 or more years ago, during a time when fire was a far more dominant force. In some respects, today's forests have more diversity and distribution of age classes as a result of fire suppression efforts, which means older age classes remain longer than they did under historical 40-year fire cycles. Yet, at the same time harvesting and linear disturbance due to industrial development (e.g., agriculture and petroleum exploration) have become predominant human impacts on forest ecosystems. Whether human impacts result in a measurably poorer condition of forest ecosystems relative to natural disturbances such as fire is difficult to determine. At best, we can only assess the trends in the condition of a forest by the degree to which human impacts have affected the flow of resources and services (if these can be measured) from forests.

Overall these indicators send mixed signals about the long-term social and ecological conditions of Alberta's forests in terms of both timber and non-timber capital. These conditions are examined in greater detail in this report.

The rates of decline in the above indicators of forest conditions are long-term trends and may mask trends in the 1990s and the projected changes in land use impacts. In particular, the escalating trends in land use impacts due to industrial (oil and gas) commitments on the forest land base will be significant, considering:

1. expected rate of new conventional petroleum activities throughout Alberta;
2. expected rate of new conventional petroleum activities in focused geographic areas of Alberta, such as the Eastern Slopes for natural gas;
3. massive in situ exploration and development throughout the northeast quarter of Alberta; and,
4. new forestry allocations and developments.

4. Shortcomings of GDP

The GDP and national-provincial income accounts ignore the value of natural capital and whether or not natural capital is being depleted at unsustainable rates. In a sense, the economic accounts treat the services of forests as "free," so markets ignore them. While the GDP records the value of each tree converted to lumber or paper, the GDP accounts provide no record of either the costs (depletion) or benefits (accretion) of forest ecosystem services. While we may be harvesting timber at unsustainable levels, the GDP would ignore this unsustainable reality and provide no early warning system.

The GDP and national/provincial income accounting have three primary shortcomings:

1. They fail to consider the physical condition (depreciation or appreciation) of forest capital in its many forms—timber capital, wildlife habitat, subsistence values, carbon sequestration values, watershed values, forest soils and other ecological service values. Ignoring the physical condition and long-term sustainability and the economic health of forest resources is akin to Coca Cola ignoring the value of its secret formula patent or the depreciation value of its bottling plants.
2. By considering only the monetary value of the harvest and sale of timber capital and products, the GDP fails to measure the full costs and benefits of the values of forest ecosystems. It provides no guidance on whether the forest capital will provide a sustainable income and value stream over the long term
3. By focusing on the export of forest capital as the engine of prosperity, the GDP and income accounts fail to address the issue of how much should be harvested and exported, and how much maintained for security of forest capital and forest ecosystem services for present and future Albertans.

The GDP provides no guidance for fiscal and public policy on whether Canada's or Alberta's forest capital values are sustainable or renewable in physical and economic terms in the medium to long term. How then should we measure sustainability of our forest capital assets?

5. Defining Sustainable Forests

There is no single measure to define sustainable forestry. Measures that track the trends in timber capital use and the condition or state of the timber and non-timber resources of the forest will provide the most meaningful measures to track forest sustainability. In principle, forests are renewable to the extent that they provide a sustained flow of goods and services over time. They become unsustainable or non-renewable through deforestation activities that denude land of trees and other forest capital. Deforestation also has a negative impact on forest ecosystem services.

The Alberta Forest Service, in a 1995 study *The Status of Alberta's Timber Supply*, provided these definitions of what it means to manage forests in a sustainable fashion:

> *Sustained yield means the province wants to maintain coniferous, deciduous and mixed wood forests in about the same proportion as they now exist in perpetuity [and] that the amount of timber harvested annually cannot exceed the rate of annual growth less losses due to natural causes like fires, insects and human activities such as oil and gas related operations*.[2]

The province has adopted the following definition of "sustainability" as presented in the Alberta Forest Legacy:[3]

> *Sustainability is the state in which we can be confident that the forest resource and all its values will be available to us not just today but, also tomorrow.*
>
> *The Alberta Forest Legacy will reinforce and safeguard Albertans' view of the kind of forest we want – a forest capable of providing us with diverse social and economic benefits today and tomorrow, while at the same time retaining the ecological vibrancy that has made it such a special part of our lives and our landscape.*

The Alberta Forest Management Science Council (1997)[4] presented the following definition of sustainable forest management:

> *The maintenance of the ecological integrity of the forest ecosystem while providing for social and economic values such as ecosystems services, economic, social and cultural opportunities for the benefit of present and future generations.*

Using these definitions we offer our own definition of sustainable forest management:

> ***Sustainable forest capital management means living off the interest of both timber and non-timber capital without compromising the productive capacity and integrity of the forest ecosystem to provide timber and non-timber resources and ecological services for current and future generations.***

Using this broad definition of sustainability of forests, the performance of sustainable forest management and the condition of Alberta's forests can be examined.

6. Accounting for Forest Sustainability

Tremendous progress has been made in attempting to construct an accounting framework for measuring sustainable forest management. Various frameworks have emerged including the sustainable forest management indicators developed by the Canadian Council of Forest Ministers (CCFM), the OECD forest management indicators, Statistics Canada's natural capital accounts for timber assets, the World Commission on Forests and Sustainable Development, the World Resources Institute (Global Forest Watch) forestry indicators, and the total wealth accounting by the World Bank.

None of these frameworks has yet been formally applied to Alberta in accounting for forest sustainability. The first attempt to apply the CCFM sustainable forest management indicators was by GPI Atlantic in the construction of their GPI Forest Account by Sara Wilson and Ronald Colman.[5]

We developed a system of forest accounts for Alberta based on the early work of Anielski (1992, 1996) and using the most current Statistics Canada timber asset account data for Alberta, based on the National Forest Inventory database.[6] The Alberta GPI forest account examines the condition of forest assets from 1961 to 1999 to answer these fundamental questions:

- Are Alberta's timber resources and forest ecosystem services sustainable based on historical forest use practices?
- What is the overall ecological health of Alberta's forests in terms of ecological services, watersheds, carbon sinks, wildlife habitat, forest recreation, clean air and the impacts of wildfire, insects and disease?
- What are the long-term liabilities or risks to timber sustainability and supply and to ecosystem health from forest fragmentation due to continued oil and gas development?
- What are the full costs of loss of forest ecosystem services?
- What is the real rate of return on each tree harvested?
- What are the carbon sequestration benefits of forests and forest peatlands in relation to climate change issues?

These forest accounts and the carbon accounts, first pioneered by Anielski in 1992[7] and updated in 1996,[8] were developed in consultation with Statistics Canada, which has also developed timber assets accounts in *Econnections*.[9] The Alberta GPI forest accounts track the physical condition of forest capital assets and also their full economic value as a basis for tying these values directly to other natural capital accounts and eventually to the GDP and national-provincial economic accounts.

6.1. The CCFM Criteria and Indicators

In 1993, the Canadian Council of Forest Ministers began developing sustainable forest management criteria (6), elements (22), and indicators (83) for measuring forest sustainability; however, no full accounting using these indicators has yet emerged. In addition, the OECD has proposed a series of forestry indicators (see Appendix C for detailed list). The CCFM's 83 indicators cover a range of issues and forest values: biological diversity, carbon storage and sequestration, soil erosion, watershed supply and regulation, nutrient cycling, biological control, employment, and protection of cultural and natural heritage. The only full accounting using the CCFM indicators has been the work by GPI Atlantic in their report *The GPI Forest Accounts: Ecological, Economic and Social Values of Forests in Nova Scotia* (Sara Wilson 1999) in which an attempt was made to complete all 83 indicators for Nova Scotia. While the CCFM indicators appear to cover the spectrum of sustainable forest management issues, they do not provide a simple, composite picture of forest sustainability for easy comprehension. The CCFM indicators framework also does not provide guidance on the relative importance of one indicator or group of indicators over another; all indicators are presented as equally important.

6.2. World Commission on Forests and Sustainable Development

One of the most promising suggestions for a composite measure of forest sustainability comes from the World Commission on Forests and Sustainable Development. The Commission advocates a Forest Capital Index to assess the changes in forest capital in quantitative and qualitative terms, to value ecosystem services, and to create market mechanisms to compensate for ecological services (Krishnaswamy and Hanson 1999).[10]

6.3. World Resources Institute Global Forest Watch Report

The World Resources Institute (WRI) recently teamed up with several forestry experts (Global Forest Watch Canada) to produce a report titled "*Canada's Forests at a Crossroads: An Assessment in the Year 2000*." The report contains a number of intuitively attractive indicators of the state of Canada's forests on a provincial basis. The indicators include both physical and socio-economic condition indicators including:[11]

- Forest cover indicators
- Forest extent
- Forest type
- Forest condition
- Cumulative forest development
- Watershed development
- Cleared areas (forest conversion due to harvesting and other land use development)
- Accessed forest (forest fragmentation due to access and industrial development)
- Unfragmented forest (as a measure of ecosystem integrity)
- Forest-dwelling species at risk
- Logging trends
- Forest allocation
- Rate of logging
- Natural disturbance trends
- Insect trends
- Fire trends
- Sustainability
- Sustaining long-term production
- Regeneration
- Socioeconomic value of the forest industry
- Economic value
- Global export ranking
- Forestry companies
- Jobs and wages
- First Nations and Metis

We believe these indicators provide a useful basis for reporting on the condition and sustainability of forests in Canada and have adopted the framework for accounting for the sustainability of Alberta's forests. The indicators provide the right balance between the physical conditions of the forest and the socioeconomic values. Such indicators do require some kind of benchmark (a common starting point or some notion of normal condition) against which trends in the sustainability of a forest can be assessed.

We have opted to combine the strengths of the WRI indicators of forest condition with the forest accounts developed by Statistics Canada as the basis for accounting for sustainability of Alberta's forest resources.

7. Natural Resource Accounting for Sustainability

The theory of natural resource accounting is rooted in the principles of economics, ecology, and accounting. It is founded on the notion that the stock, consumption, and natural resources and environmental services should be accounted for in the same way we account for human-made capital assets (e.g., plants, equipment, machinery). Renewable resources, such as forests, appreciate as they grow and depreciate as we deplete the timber capital stock and degrade the forest ecosystem. And maintenance investments, such as reforestation and stand tending, are required to maintain the productive capacity of the forest.

Traditional measures of economic performance (e.g., Gross Domestic Product) and our current national income accounts do not account for the value of our natural resources. While timber harvesting generates economic benefits from the production of lumber and pulp—a positive impact on GDP—any depreciation or degradation of the forest as a capital asset is unaccounted for. Resource accounting corrects these shortcomings of traditional economic measures of growth by accounting for the changes in physical stock and value of natural capital.

Environmental economists argue that the use of natural resources, particularly renewable resources, can only be sustainable as long as the productive capacity of the ecosystems that provide environmental goods and services can be maintained. That means *living off of nature's income* or *the interest on nature's capital* without compromising the productive capacity of the natural capital stock. While we can choose to live beyond nature's sustainable income stream to serve our short-term income needs (e.g., harvest at a rate greater than the growth of the timber capital), we do so at the expense of depleting the capital stock itself.

By accounting for the annual additions and all depletions[e] of the capital stock of natural resources, we can better determine whether the productive capacity of that asset base is being sustained. Table 2 illustrates the framework of a typical natural resource account balance sheet that can be applied to both renewable and non-renewable resources.

[e] These include forest growth, reforestation, and harvesting, degradation, deforestation, and natural depletions (fire, insects, disease).

Table 2: Natural Resource Accounting Framework

	a Physical Account (physical units)	b Unit Value (economic rent: $/unit production)	a x b Value Account ($)
Opening Stock			
Additions:			
Growth*			
Reproduction/Regeneration (reforestation) *			
Extensions			
Revisions			
Reductions:			
Production (harvesting)			
Deforestation*			
Natural Causes* (fire, insect, disease, natural mortality)			
Net Change = Additions – Reductions			
Revaluations			
Closing Stock = Opening Stock + Net Change			

Source: Repetto, Robert et al. (1989). *Wasting Assets: Natural Resources in the National Income Accounts*. World Resources Institute, Washington, D.C.
* Items marked are specific to forest resources; all other categories are applicable to subsoil minerals; e.g., oil and gas.

The strength of natural resource accounting is that it provides a framework within which the issue of sustainability can be assessed. The framework provides a means of (a) exploring the interdependence of various natural capital assets and resource-based sectors of the economy, and (b) organizing often fragmented and disjointed information into a kind of a natural capital "balance sheet." For example, while we tend to devote effort to collecting forest inventories, land use depletion statistics, and fire statistics, there is no single balance sheet that reconciles or integrates this information into a picture of sustainability. The balance sheet is the sustainable volume of timber that takes all factors into consideration using the inventory snapshot, accounting for additions and reductions to the inventory from human and natural impacts.

A natural resource account can look at depletions of forest capital due to harvesting, fire, insects, disease, and other land use development impacts, and compare them with the annual growth of the original and the newly established forest. As long as depletions and additions are in balance we know that the capital stock of timber is being maintained. These accounts can be presented in both physical terms (e.g., timber land area and timber supply) and monetary terms (e.g., economic value of the timber supply and economic value of annual depreciation).

Traditional forestry indicators of sustainability, such as annual allowable cut[f] or the long run sustained yield, while still valid, have their inherent weaknesses. Annual allowable cut (AAC), for example, while traditionally a good proxy for the maximum sustainable level of harvest, is often inconsistently applied by provinces and does not allow consecutive time series of data to be compared. AAC also may hide some of the details of how annual growth rates and depletion rates affect overall timber capital stock. AACs are developed on a Forest Management Unit or Forest

[f] Annual Allowable Cut, or AAC, is the annual amount of timber that can be harvested (determined by government foresters) on a sustainable basis within a defined planning area.

Management Agreement basis. They are reviewed by the provincial government at least every 10 years and are revised accordingly. Fluctuations in the approved AAC are a result of the following factors:

- updated forest inventory and new growth and yield information;
- changes in the available land base (i.e., changes to provincial parks and other reserved areas);
- new administrative boundaries including Forest Management Agreement Areas and Forest Management Unit amalgamations;
- updated analysis procedures;
- harvest analysis changes;
- updating the net land base for catastrophic events such as fire; and
- changing management strategies.

Natural resource accounts provide a full disclosure of the depletions and additions to the capital stock in the structure of a balance sheet, and reconcile these two sides of the ledger. The physical and monetary information contained in the accounts speaks to the forester, biologist, economist, accountant, and politician alike. The accounting framework also provides a means of comparing, for example, the stock of timber capital with wildlife, energy, and water resources and revealing some interdependence. Trends in depletion and additions to natural capital stocks can be evaluated. Accounts can also be compared across regions, provinces, and nations.[g] Decision makers, empowered with such information, will be better equipped to make sustainable development decisions. The major shortcoming is the availability of data or resource inventories and inconsistencies in timber inventories over time due to different methodologies. We acknowledge the forest inventories were never designed to track an explicit time series accounting of accrual and withdrawals to the forest land base, thus making it difficult to project backwards in time productive forest area or standing volume of timber. This is a major shortcoming for completing longitudinal forest accounts that provide a meaningful assessment of forest sustainability. Nevertheless, the construction of accounts using historical data on depletions and estimates of growth is possible, assuming a given starting point or benchmark year is agreed upon.

8. Alberta Forest Resource Accounts

The Alberta GPI forest accounts are based in part on the timber asset accounting framework developed by Statistics Canada in *Econnections*—the Canadian System of Environmental and Resource Accounts (CSERA)—which includes environmental and resource accounts for timber assets, subsoil assets (oil, gas, coal, minerals) and land accounts.[12] These natural resource accounts are meant to complement the Canadian System of National Accounts (CSNA) and, when natural capital is measured in monetary value terms, could be seen as an extension of the National Balance Sheet Accounts. The CSERA have not become fully integrated into the CSNA but rather reside as satellite addenda, at best. First published in 1997, the CSERA have been updated to 2000[13] and recently released by Statistics Canada.

CSERA provides a comprehensive framework for linking the economy and the environment through physical and monetary statistics. The CSERA contain three main components:

- Natural Resource Stock (and flow) Accounts to measure quantities of the stocks and annual changes in natural resource stocks;

[g] Cross-jurisdictional comparisons must be made with caution, given differences in provincial inventory systems and in the underlying inventory data.

- Material and Energy Flow Accounts to record the physical flow of natural resource materials and energy between the economy and environment; and
- Environmental Protection Expenditure Accounts that track current and capital expenditures by households, business and government on protecting the environment.

The timber asset accounts, as part of the CSERA developed by Statistics Canada comprise two accounts—one physical and one monetary—to account for the stock, flow and economic value of Canada's timber assets. The timber accounts use provincial/territorial and national forest inventory data and cover the period from 1961 to 1997. Canada's Forest Inventory 1991 (CanF191), developed by Natural Resources Canada[14] in cooperation with provincial/territorial forest ministries, is used as the starting point from which the timber capital inventory is literally "grown" forward to 1997 and backwards to 1961 using a modified population growth model developed at Statistics Canada. From the base inventory year of 1991, the timber capital area and volume accounts are grown through time simulating the impact of growth, harvesting, natural loss (mortality and fire) and other changes in timber capital stock. The growth model assumes that each age class of trees moves up one age increment with corresponding volume increment on the total forest land base, adjusting for depletions of growing timber capital due to harvesting and natural disturbance. This type of modeling, though conceptually similar to a population model, is similar to timber supply analyses done by provincial forest managers, including the Alberta Land and Forest Service (LFS).

The Alberta GPI forest accounts include a timber volume account and productive forest timber area account based on National Forest Inventory data and Alberta LFS data (see Tables 3 and 4). The monetary timber asset account, which provides an economic value accounting of timber capital, is based on Statistics Canada's Monetary Timber Asset Account in *Econnections*. Estimates of the full economic costs and benefits of forest service values are drawn from various sources, including research studies and academic papers. Table 3 shows the closing stock of timber capital over time adjusting for annual growth, harvesting, fire, natural mortality, and deforestation due to industrial land use. Table 4 shows the changes in the productive forest land area and the magnitude of impacts based on the same variables in the timber volume account.

The timber asset accounts are important since they provide a long-term view of changes in the physical stock of timber capital, the annual increment, and annual depletion rates (both harvesting and natural disturbance). However, they do not express any opinion on whether these trends in inventory are sustainable or not. This is left for analysts to determine and debate.

This Alberta timber resource account for 1999 is the fourth such account since 1991 when Anielski (1992) prepared the first timber resource account for Alberta (and Canada). The accounting framework used is based on the pioneering resource accounting work of Robert Repetto (1991) for Indonesia and Costa Rica and on the United Nations *SNA Handbook on Integrated Environmental and Economic Account* (1991). These original frameworks were refined by Statistics Canada in developing *Econnections*. The new *Econnections* accounts for 2000 were published in spring 2001.[15] The release of *The Status of Alberta's Timber Suppl*y by Alberta Environmental Protection (1996) also provided estimates of an average provincial timber growth rate useful in constructing the Alberta timber volume accounts.[h]

[h] As is noted elsewhere, it is unfortunate that annual provincial growth estimates are not available for each year in our accounting period (1961 to 1999) to provide a more accurate reflection of the "interest rate" on timber capital.

Table 3: Alberta Timber Volume Account

Alberta Timber Volume Account

('000 cubic meters)

	Opening Stock	Annual Increment	Reductions					Net Change	Closing Stock
Year		**Growth**	**Harvest**	**Fire**	**Deforestation due to Other Land Use**	**Mortality**	**Total Depletions**		
1961	1,657,109	27,885	3,352	673	1,613	3,700	9,338	18,546	1,675,656
1962	1,675,656	27,675	3,729	20	1,613	3,568	8,929	18,746	1,694,402
1963	1,694,402	27,535	3,779	51	1,613	3,423	8,866	18,670	1,713,072
1964	1,713,072	27,443	3,525	27	850	3,285	7,688	19,755	1,732,827
1965	1,732,827	27,314	3,584	81	926	3,156	7,747	19,568	1,752,394
1966	1,752,394	27,635	3,689	97	2,606	3,032	9,424	18,211	1,770,606
1967	1,770,606	27,347	3,151	30	2,280	2,914	8,375	18,972	1,789,578
1968	1,789,578	27,148	3,703	2,697	1,855	2,805	11,060	16,087	1,805,665
1969	1,805,665	26,961	4,128	1,172	1,695	2,699	9,694	17,267	1,822,931
1970	1,822,931	26,807	4,143	1,614	1,358	2,598	9,713	17,094	1,840,026
1971	1,840,026	26,825	4,138	567	1,316	2,504	8,526	18,299	1,858,325
1972	1,858,325	26,464	4,893	2,943	1,264	2,415	11,515	14,949	1,873,274
1973	1,873,274	26,257	5,599	27	1,283	2,331	9,239	17,018	1,890,292
1974	1,890,292	26,405	5,058	1,311	1,209	2,249	9,826	16,579	1,906,870
1975	1,906,870	26,434	4,963	33	1,188	2,173	8,357	18,078	1,924,948
1976	1,924,948	26,138	5,627	1,070	1,322	2,101	10,121	16,017	1,940,965
1977	1,940,965	26,177	6,370	3	1,551	2,033	9,957	16,220	1,957,185
1978	1,957,185	25,937	6,519	116	1,107	1,968	9,710	16,228	1,973,413
1979	1,973,413	25,744	6,995	4,251	1,008	1,901	14,155	11,589	1,985,002
1980	1,985,002	25,493	5,933	16,437	3,454	1,822	27,645	-2,153	1,982,849
1981	1,982,849	24,950	6,586	24,993	3,405	1,729	36,712	-11,762	1,971,087
1982	1,971,087	24,685	5,714	23,269	3,585	1,757	34,325	-9,640	1,961,448
1983	1,961,448	24,331	7,344	62	5,535	1,805	14,747	9,584	1,971,032
1984	1,971,032	24,987	8,457	669	4,640	1,846	15,612	9,375	1,980,407
1985	1,980,407	27,370	8,979	279	4,356	1,881	15,495	11,875	1,992,282
1986	1,992,282	31,089	10,387	96	5,011	1,912	17,407	13,682	2,005,965
1987	2,005,965	28,002	10,496	1,837	7,605	1,936	21,874	6,128	2,012,093
1988	2,012,093	24,673	11,990	702	3,978	1,958	18,627	6,046	2,018,139
1989	2,018,139	24,874	12,393	211	3,369	1,974	17,947	6,926	2,025,065
1990	2,025,065	24,736	11,911	2,269	(841)	1,986	15,325	9,411	2,034,477
1991	2,034,477	24,714	12,926	165	(26)	1,996	15,061	9,654	2,044,130
1992	2,044,130	24,632	14,594	81	684	2,003	17,362	7,270	2,051,400
1993	2,051,400	24,639	14,897	1,468	3,067	2,005	21,438	3,201	2,054,601
1994	2,054,601	24,052	19,790	1,014	1,820	2,005	24,629	-578	2,054,024
1995	2,054,024	23,793	20,287	22,108	1,747	1,988	46,130	-22,336	2,031,687
1996	2,031,687	23,771	20,037	106	1,092	1,977	23,213	558	2,032,246
1997	2,032,246	23,530	22,227	261	4,271	1,965	28,724	-5,194	2,027,051
1998	2,027,051	23,432	17,000	47,074	2,939	*1,965*	68,978	-45,545	1,981,506
1999	1,981,506	23,399	23,000	7,889	4,143	*1,965*	36,998	-13,599	1,967,907
Totals		**1,011,285**	**351,893**	**167,774**	**91,490**	**89,330**	**700,487**	**310,798**	
Annual Averages		25,930	9,023	4,302	2,346	2,291	17,961	7,969	

(Source: Alberta Forest Service and Alberta Environment statistics and Statistics Canada Timber Resource Accounts.

Statistics Canada. 2001. Econnections: Linking the Environment and the Economy: Indicators and Detailed Statistics. Cat. No. 16-200-XKE, February 2001, Ottawa

1. Growth is derived from Statistics Canada Alberta timber volume account models which uses a population modeling approach to estimate annual increments of volume and area to the next age class netting out land use impacts; the average MAI from the Stat Can model is 1.438 m3/ha/yr which is lower than Alberta Forest Service estimates of 1.98 m3/ha/yr

2. Closing Stock balances are calculated using opening stock balance plus annual volume increment (growth) less total depletions (harvest, fire, mortality (insect and disease), deforestation (land use) and land use deletions.

3. Harvest and fire statistics are from Alberta Forest Service data

4. Mortality estimates are from Statistics Canada's timber capital model and would include mortality from insect infestation and disease. While we did have area of forest infested with insect or disease we were unable to determine how much timber volume succumbed to mortality.

5. The 1997 closing stock volume from Statistics Canada Alberta timber accounts is used as the starting point for reconstructing the closing stock volume figures back to 1961.

Table 4: Forest Area (Productive) Account

Alberta Productive Forest Land Area (hectares)

Year	Opening Stock of Productive Forest Land	Additions to Forest Land (ha)	Forest Land Impacts and Deletions: Harvest (ha)	Fire (ha)	Insect and Disease (ha)	Deforestation due to Other Land Use (ha)	Net Change in Productive Forest Land (ha)	Closing Stock of Productive Forest Land: Forest (ha)
1961	18,377,320	0	13,000	32,643		15,174	-15,174	**18,362,146**
1962	18,362,146	0	13,000	876		15,174	-15,174	**18,346,972**
1963	18,346,972	0	13,000	3,158		15,174	-15,174	**18,331,798**
1964	18,331,798	0	13,671	1,578		7,394	-7,394	**18,324,404**
1965	18,324,404	0	14,241	12,205		8,049	-8,049	**18,316,355**
1966	18,316,355	0	14,426	5,244		22,658	-22,658	**18,293,697**
1967	18,293,697	0	12,040	2,711		19,826	-19,826	**18,273,872**
1968	18,273,872	0	11,506	157,027		16,133	-16,133	**18,257,739**
1969	18,257,739	0	17,213	12,056		14,739	-14,739	**18,243,000**
1970	18,243,000	0	16,961	15,829		11,804	-11,804	**18,231,196**
1971	18,231,196	0	17,046	7,431		11,445	-11,445	**18,219,750**
1972	18,219,750	0	20,620	25,244		10,994	-10,994	**18,208,757**
1973	18,208,757	0	20,672	225		11,153	-11,153	**18,197,604**
1974	18,197,604	0	18,242	11,178		10,512	-10,512	**18,187,091**
1975	18,187,091	0	20,677	555	6,000	10,326	-10,326	**18,176,765**
1976	18,176,765	0	20,635	7,776	0	11,496	-11,496	**18,165,269**
1977	18,165,269	0	21,567	275	0	13,486	-13,486	**18,151,783**
1978	18,151,783	4,730	24,333	2,175	3,000	9,629	-4,899	**18,146,884**
1979	18,146,884	16,105	24,689	121,060	2,875,000	8,769	7,336	**18,154,220**
1980	18,154,220	0	20,605	413,381	1,750,000	30,034	-30,034	**18,124,186**
1981	18,124,186	223	26,933	395,792	3,000,000	29,607	-29,384	**18,094,802**
1982	18,094,802	0	35,083	280,682	4,291,000	31,175	-31,175	**18,063,627**
1983	18,063,627	1,411	29,904	1,073	1,320,000	48,129	-46,718	**18,016,908**
1984	18,016,908	43,239	34,097	21,650	2,000	40,351	2,888	**18,019,796**
1985	18,019,796	12,012	39,861	2,894	156,000	37,874	-25,863	**17,993,934**
1986	17,993,934	27,481	40,277	1,617	316,000	43,574	-16,093	**17,977,841**
1987	17,977,841	20,886	44,054	22,841	1,328,000	66,128	-45,243	**17,932,598**
1988	17,932,598	9,036	43,488	3,456	2,827,000	34,589	-25,553	**17,907,045**
1989	17,907,045	2,172	47,178	2,272	1,276,000	29,297	-27,125	**17,879,920**
1990	17,879,920	40,398	47,671	19,743	1,537,000	(7,309)	47,707	**17,927,628**
1991	17,927,628	36,740	50,468	1,432	270,200	(230)	36,970	**17,964,598**
1992	17,964,598	0	53,147	705	34,200	5,945	-5,945	**17,958,652**
1993	17,958,652	1,336	57,080	12,769	65,500	26,674	-25,337	**17,933,315**
1994	17,933,315	0	74,298	8,819	355,600	15,829	-15,829	**17,917,486**
1995	17,917,486	0	65,321	192,241	494,000	15,192	-15,192	**17,902,294**
1996	17,902,294	31,624	61,105	926	337,784	9,497	22,127	**17,924,421**
1997	17,924,421	0	62,738	2,271	195,059	37,137	-37,137	**17,887,284**
1998	17,887,284	0	61,222	409,337	467,042	25,554	-25,554	**17,861,730**
1999	17,861,730	0	61,222	68,601	774,788	36,027	-36,027	**17,825,703**
Totals (1961-1999)		**247,393**	**1,283,291**	**2,281,749**	**23,681,173**	**799,010**	**-551,617**	

Source: Statistics Canada, "Econnections", Alberat Forest Resource Accounts. Various statistics from Alberta Environmental Protection and Alberta Environment Protection (1996) "The Status of Alberta's Timber Supply"

Notes: 1. Stock balances for 1964-1998 are derived based on 1999 Alberta Forest Service timber inventory estimates which estimate 17,825,703 hectares of productive forest land.

2. Closing stock balances are estimated and projected back in time using the net loss or gain in productive forest land due to land use deletions.

3. Productive forest land (roughly 59 % of Alberta's Green Area) is public forest land area suitable for timber harvesting.

4. We assume that the area harvested, burned, infested by insects, or returned to forest land, while disturbed and depleted of timber, remains part of the productive land base, thus are not deleted.

5.Deforestation results from land use changes such as agricultural development, linear disturbance (ii.e.seismic lines, roads,powerlines, pipelines), and mineral surface leases are treated as permanent deletions from available productive forest land.

6. "Net change" is the reduction in productive forest land due to deforestation from linear disburance plus additions from conversion back to forest land from agricultural land use.

The timber capital account is constructed based on the resource account framework shown in Table 5 below.

Table 5: Physical Timber Account

TIMBER ACCOUNT FRAMEWORK

Physical Account (1) (productive forest land area)* (hectares)	Physical Account (2) (timber volume) (cubic metres)	Value Account**
[1] Opening stock		
Additions:		
[2] Natural growth		
[3] Land use additions		
Reductions:		
[4] Harvest		
[5] Fire		
[6] Mortality (Insects and disease)		
[7] Loss due to roads, energy and agriculture development		
[8] Closing stock [1+2+3-4-5-6-7]		

* accounts for only the publicly-owned productive, non-reserved provincial forest land area.
**The economic value of timber capital is based on applying economic rent (economic rent = price less costs of production) estimates by Statistics Canada *(Econnections)* for Alberta and other provinces.

The account assesses both the public productive forest land base (or merchantable forest land) and the total and merchantable timber growing stock. The account begins with the annual opening balance of forest land and timber volumes. The volume account differs somewhat from the area account. Additions to volume of timber capital result from growth on the stocked portion of productive forest land. Additions to the forest area land base come from afforestation or reconversion of agricultural land back to forest land. Depletions in volumes result from harvesting, fire, natural mortality due to insect infestation and disease[i], and land use disturbances (energy development, roads, powerlines, agricultural expansion). Depletions in area of forest are due to forest land conversion to other uses.

It is possible to show net changes in the area and volume of forest and timber capital using the detailed additions and depletions information. A time series of the annual and cumulative impacts of industrial and natural disturbances or depletions can be derived. The account tells us whether the current use of Alberta's timber capital is sustainable.

Data for the account covering 1961 to 1999 came primarily from the Alberta Forest Service, the National Forest Inventory or Statistics Canada. For the most part, time series data on depletions due to harvest, fire, insects, disease and land use were available. Time series estimates of the annual increment or growth rate of timber capital were not available with the exception of a single growth rate of 1.98 m^3/ha estimated by Alberta LFS using Phase 3 Forest Inventory data.[16] In previous timber resource accounts, Anielski (1992, 1994, 1996, 1997) used estimates from

[i] While government estimates of the area of forest that has been infested with insects or disease are available, estimates of the actual volume of timber affected (i.e., mortality) as a result of infestation are not available. We have thus relied on Statistics Canada's modeled estimates of mortality for Alberta as the best estimate of tree mortality from natural causes, which includes insects and disease.

Canadian Forest Service studies. With the release of *The Status of Alberta's Timber Supply* in 1996 the Alberta LFS revealed an average provincial growth rate of 1.98 m^3/ha/yr. Efforts are now being made to derive new timber yield tables compiled on a natural subregion basis that will provide a more accurate estimate of growth rates on the productive forest land base at the provincial scale. Statistics Canada's timber asset accounts use a population modeling approach, growing the forest by age class increments through time rather than applying an average growth rate figure to the forest land base.

Because of the incompatibility of three historical Alberta timber supply inventories,[j] one of the most challenging issues of the timber accounting exercise is establishing a defensible starting balance for area and timber volume. The Alberta GPI timber account begins with the 1999 estimates of productive forest area, based on updated Phase 3 inventory data, provided by the Alberta LFS. This starting point is then used to "grow" the timber supply back in time to 1961 using actual depletion statistics and estimates of annual growth of the provincial growing timber inventory.[17]

There are some inherent structural weaknesses and apparent problems with the timber resource account that relate primarily to the data. First, there are significant differences between the forestry data sets used by Statistics Canada and those of Alberta LFS. Specifically, the area harvest figures shown by Statistics Canada are almost double those reported by the LFS even though the total volume harvest figures are comparable. The discrepancy is due partly to the way Statistics Canada calculates harvest area, working from volume harvest figures reported by forest industry mills in terms of fibre input to their mills, then using an average stocking rate for Alberta's forest types. The LFS harvest area figures are much lower, which may be partially due to not accounting for private land area harvested to meet fibre demand by mills.[k] The discrepancy in harvest area figures is significant.[l] We opted to use the LFS harvest area figures given the confidence that the LFS had in these figures. However, we are concerned that the harvest area reported may significantly underestimate the total impact of forestry operations on both public and private forest land sustainability and that long-term timber supplies may be at risk. This is because we generally know very little about timber harvest and sustainability on private forest land even though this timber capital is an important contributor to Alberta forest products.

We were unable to resolve the discrepancy between the LFS figures and Statistics Canada figures even after discussions with LFS.[18] What is apparent is the importance of understanding the extent and impact of private forest land logging vis-à-vis public forest harvesting to meet the long-term timber requirements of Alberta mills.[19]

The second major concern is with the annual growth rate—the increment, or "interest," on total timber capital.[20] Statistics Canada timber capital accounts for Alberta reveal an annual growth average of 1.438 m^3/ha/yr (ranging from 1.315 m^3/ha/yr to 1.723 m^3/ha/yr). This is lower than the LFS estimated growth rate of 1.98 m^3/ha/yr.[21] In the first Alberta timber resource accounts developed by Anielski (1992) the average annual growth was estimate at only 1.35 m^3/ha/yr.[22] The discrepancy between LFS growth estimates and Statistics Canada growth estimates is due to Statistics Canada using a population modeling approach to "grow" age-classes of timber area and

[j] Phase 1 in 1964, Phase 2 and Phase 3 in 1984

[k] The private forest land base has not been as extensively quantified as Crown forest land. Several initiatives are underway to extend the coverage of forest classification in Alberta beyond the Green Area.

[l] The discrepancy is best revealed by estimating the apparent yield of timber harvest comparing LFS harvest volume figures with harvest area figures, which shows a yield or stock rate considerably higher than their own timber volume inventory table for 1999.

volume back in time, rather than a single growth estimate by the LFS. In the Alberta GPI accounts we perform sensitivity analysis in the Timber Sustainability Index calculations using both LFS and Statistics Canada growth figures. Future work by the Alberta Forest Service in developing new yield tables will help resolve at least some of these discrepancies.[23]

The third concern is with Statistics Canada's timber asset accounts, which until now only considered the impact of roads in the timber account. They ignored the significant impact of linear disturbance such as seismic lines, pipelines, powerlines, oil and gas well-sites, agricultural development, and other land use developments. The Alberta GPI forest accounts consider the accumulated impact of all land use disturbance. The Pembina Institute is now working closely with Statistics Canada, in consultation with the Alberta LFS, to modify the Alberta timber asset accounts to accommodate linear disturbance impacts other than roads.

Notwithstanding these weaknesses, we believe the Statistics Canada timber asset accounting model and architecture is conceptually and operationally sound for assessing the sustainability and condition of the timber capital in a forest. Improvements to the accuracy of land use impacts in the database will be required.[24] The Alberta GPI forest accounts use the architecture of the CSERA; however, we use reported or actual area and volume estimates for harvest, linear disturbance, fire, insect and disease (natural mortality) data from Alberta Environment and Alberta Forest Service to construct the accounts. We conducted some sensitivity analyses on the assumed growth rate that is built into Statistics Canada timber volume tables, applying both the Statistics Canada annual assumed growth increment as well as the estimated provincial mean annual increment of 1.98 m^3/ha/yr to provide two estimates of timber sustainability.

The results of the Alberta GPI timber capital accounts were referenced earlier (Table 3, Timber Volume Account[25] and Table 4, Productive Forest Area Account), and a wealth of information and indicators of sustainability can be drawn from the volume and area accounts.

9. Forest Sustainability Indicators

9.1. Indicator 1: Timber Sustainability Index

While few simple measures of timber sustainability have emerged, we believe that an intuitive expression of sustainability is the ratio of the annual timber growth to total depletions. We call this the Timber Sustainability Index (TSI). The OECD has recommended a similar indicator[m] for assessing forest sustainability.[26]

Using data from the Alberta timber volume account in Table 3 we can derive the TSI for any given year for the provincial public forest land base. The TSI is derived from estimates of the annual increment of total standing timber supplies. There is some uncertainty about the exact annual growth rate to use in this calculation, depending on whether we use Statistics Canada's timber asset account for Alberta to derive an annual growth rate (which varies by year but averages roughly 1.47 m^3/ha/yr) or the Alberta LFS 1996 estimate of 1.98 m^3/ha/yr. In the denominator of the TSI ratio is the cumulative impact of timber removed through harvesting and land use deforestation and/or through natural causes. Normally, such ratios only consider timber harvesting impacts but this is too narrow given the importance and magnitude of fire and oil, gas and agricultural impacts. If the TSI ratio of growth to total depletions is greater than one, this means that the forest is growing faster than it is being depleted—that is, we are living sustainably off the interest of the forest capital stock. A TSI of less than one means that we are drawing down timber capital stock at unsustainable levels that will eventually deplete the inventory, reducing timber volume available for future forest industry production.

The Alberta government reports timber sustainability as the ratio of harvesting to the annual allowable cut.[n] In principle, foresters note that as long as the level of harvest does not exceed the calculated AAC, timber sustainability is being achieved. However, this accounting for timber sustainability has several shortcomings. First, the AAC itself is a calculated metric of overall timber sustainability, but the AAC is like a "black box" with no transparency in terms of the data and assumptions used in its calculation by the province's professional foresters. In theory, the AAC should explicitly incorporate growth and yield changes and impacts of land deletions, linear disturbance and natural disturbance like fire and insects. However, the AAC figures are reported as a given "bottom line" without these details. Thus when interpreting the ratio of harvest to AAC as the sole proxy for timber sustainability, the reader must effectively trust the accuracy of the AAC calculation Indeed, we could not confirm where provincial AAC calculations in fact considered all forest impacts or what growth and yield assumptions were used.[27] Second, if the AAC calculation ignores the impacts of some land use and natural disturbance impacts then using a ratio of timber harvest to AAC alone would tend to overestimate sustainability by ignoring the cumulative impact on timber supply from non-harvest impacts.

The TSI and GPI timber resource accounts provide the basis for examining the validity of the calculated AAC figures by making the detailed components for assessing timber sustainability more transparent. This transparency has led to some concerns about the reliability and confidence in the AAC calculations. In particular, uncertainty about the exact rate of timber growth at the provincial forest land base scale leaves some doubt about the confidence in AAC calculations and

[m] OECD has recommended a ratio of annual depletion to productive capacity (growth).
[n] This measure is used in *Measuring Up*, the Alberta Government's annual performance report card.

thus in timber sustainability in general.[o] More work is required to develop more accurate measures of timber capital growth rates at both a provincial and forest management unit scale.

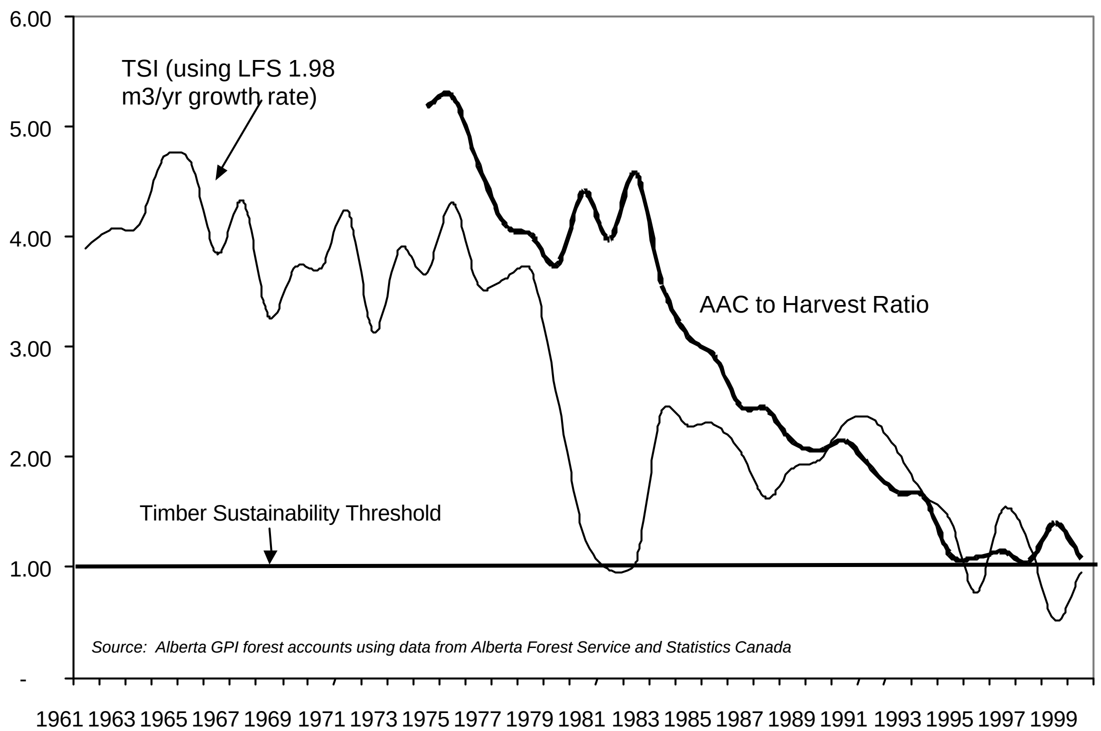
We have calculated the TSI using Statistics Canada's timber asset accounts for Alberta for deriving annual timber growth estimates and natural mortality rates and Alberta Environment (Alberta Forest Service) statistics for harvest, fire, insect/disease, and deforestation due to land use impacts. The data used to calculate the TSI are shown in Table 3.

We also conducted sensitivity analyses estimating three TSIs. The first used Statistics Canada's *Econnections* Alberta timber volume and area account figures to calculate the TSI. The second used the Alberta GPI forest account data (based on Alberta LFS data) for total volume depletions and Statistics Canada's annual growth estimates. The third TSI used Alberta GPI forest account total depletion figures but an annual average growth figure (based on LFS 1996 estimates) of 1.98 m^3/ha/yr.

The results are sobering. As Figure 1 shows, when we consider the cumulative impact of harvesting, fire, mortality (insects and disease), and deforestation from land use and industrial development impacts. Figure 1 suggests that the sustainability of Alberta's timber capital became unsustainable in the latter part of the 1990s.

[o] The first estimates of Alberta's timber capital accounts by Anielski (1992) had no official average annual provincial growth estimate for timber capital. Then in May 1996, Alberta Environmental Protection (Alberta Forest Service) released its report *The Status of Alberta's Timber Supply*, providing the first provincial growth estimate of 1.98 m^3/ha/yr. Applied to the total productive forest land base, this suggested that "the annual growth of all inventoried public forested lands in the province has been estimated at 44.5 million cubic metres… [compared with] the total net annual allowable cut [AAC] within the Green Area [of] approximately 22.1 million cubic metres" (Alberta Environmental Protection, 1996, p. 16). The conclusion was that there was a significant surplus of timber capital available that would satisfy demand even up to full harvest of the AAC (at the time, 1994/95 the provincial harvest was only 15.1 million cubic metres or 34 percent of the total annual growth). The estimated growth rate of 1.98 m^3/ha/yr is significantly higher than Anielski found in his 1992 study. Based on Canadian Forest Service estimates, annual growth rates have been estimated as low as 1.35 m^3/ha/yr. In previous accounts, this much lower growth figure produced lower TSI figures, suggesting serious concerns about timber sustainability. New growth and yield estimates being calculated by Carl Peck for the Alberta Forest Service should provide more accurate measures of timber growth rates for Alberta's forest ecosystems. What is important is the significant range of estimates of growth suggesting considerable uncertainty about the most important part of the sustainability equation—the interest rate on timber capital stocks.

Figure 1: Alberta Timber Sustainability Index (TSI) vs. AAC to Harvest Ratio, 1961 to 1999



While all three TSI estimates vary slightly due to different growth rates and other depletion figures, they all show the sustainability threshold (TSI = 1.00) being first breached in 1980 to 1982 and then repeatedly between 1994 and 1999. The Statistics Canada TSI figures reveal a more depressed TSI due to the use of a lower annual increment rate but lower estimates of land use depletion impacts. The Alberta GPI TSI is likely more realistic since it incorporates total land use impacts even though it may overestimate timber capital growth. The LFS growth TSI yields the most favourable results due to a higher growth rate assumption, yet it too fell below the timber sustainability threshold in the past four years. The breach in 1981 and 1982 was due to the impact of catastrophic fires. In the 1990s the TSI drifted to what might be called the "timber sustainability threshold" where total annual depletions exceed annual growth of timber capital. In 1995 the TSI fell below the sustainability threshold and then again in 1998 and 1999 reaching its lowest historical level in 1998 at 0.47 due to large fires and the cumulative impact of linear disturbance. This means that the annual growth in 1998 was only 51 percent of the total volume depleted or, conversely, total depletions were 1.95 times annual growth. This low TSI compares to an all-time TSI high of 4.72 in 1964.

This trend is due mainly to combined impacts of timber harvesting, fire in the 1990s and the accumulated impact of deforestation and fragmentation due to linear disturbance from oil and gas, pipeline, powerline, roads and agriculture development. Much of the oil and gas activity on the forestland base results in long-term deforestation.

There are just as many shortcomings to the TSI calculation as there are with interpreting the ratio of harvest to AAC. Both, we believe, suffer from a common shortcoming of irregular and incomparable forest inventories over time and the complexity of maintaining accurate timber inventory "balance sheets" using estimates of annual growth and depletion data. As Daryl Price of Alberta LFS has noted:

> *There is potential for double counting as a significant portion of the volume from forest land area impacted by other industrial users is actually salvaged and utilized by Alberta's forest industry. There is a mixing of terms here; there is confusion between "standing volume" and "growth." The AAC takes standing volume into account, while growth is used to predict future sustainability. The terms cannot be used interchangeably nor can they be inappropriately mixed. How did fire affect the net land base? The forest inventory records fire damage to the productive land base. How did oil and gas activities affect the net land base? Although these impacts cannot be directly quantified from the existing forest inventory data, the difference is likely significant when compared to the gross land base impact (i.e., simply taking total hectares affected). Insect and disease are implicit in AAC determination. Endemic insect and disease effects are accounted for in growth estimates.*[28]

To us, this simply confirms the need for more transparency of data and assumptions regardless of how timber sustainability accounting is conducted.

Conducting TSI analysis at the Forest Management Unit or forest region level would be beneficial, revealing where timber sustainability is most at risk in the province. This would require the same kind of detailed information on growth and depletions as at the provincial scale. Indeed, this scale of analysis might provide more meaningful insight into where individual forestry companies may be most at risk of timber supply shortages due to fire, insect, disease or sustained industrial activity.

9.1.1. The Potential End of Old-Growth Forest

An important question that arises as timber capital is depleted by harvesting, industrial development and natural disturbance, is how many years remain until the old-growth or "overmature" timber stock is fully depleted? While useful to portray total timber supply sustainability, the TSI provides little information on how much of the "overmature" age classes (80 year or older trees) or "old growth" (by some definitions) remains. We might define overmature age classes as those trees that are 70 years or older for deciduous/hardwood trees such as aspen, poplar and birch, and 100 years or older for coniferous/softwood trees like spruce, pine and fir.

Forests are managed on a "sustained yield" basis. This effectively means timber is harvested on a regulated basis where the oldest trees are harvested first; eventually there will be a regulated forest of largely even-aged forest age classes. In plain language this means liquidating old-growth (or "overmature" in the language of foresters) trees and moving to a managed forest where just-in-time inventory is practiced. In this system, trees are allowed to grow to maturity and are then harvested. This is done primarily for economic reasons by harvesting at the maximum sustained yield when trees have reached their peak annual growth increment.

To the layperson this means that old-growth trees are being systematically removed from the timber inventory. This process of old-growth depletion is accelerated by the cumulative impacts of oil and gas, agriculture, pipelines, powerlines, roads and natural disturbances from fire and insects. How many years are left until Alberta's old-growth forest is gone? That depends on our assumptions about the continued rate of annual growth and total depletion rates. The GPI forest accounts can be used to forecast this end-of-old-growth event by using historical rates of growth and total depletion impacts.

We have attempted to model when the last remaining stock of overmature/old-growth timber would be exhausted due to the cumulative effects of harvesting, land use, and natural disturbance. First, we assume that 1999 harvest levels continue into the future and that the average 10-year cycles of forest fires, insect mortality and land use depletions continue. Second, we assume that younger trees grow incrementally, adding to the supply of overmature timber age classes,[p] net of any loss of "immature" age classes due to natural disturbance and land use impacts (again based on the last 10-year averages). We also assume successful reforestation of harvested, burned and industrially-disturbed forest land, thus adding to the young age classes of timber which also grow through time.

With this model, we can estimate, based on these cumulative effects, in what year the last stands of overmature/old-growth will be fully depleted leaving a relatively even-aged forest that is managed such that trees grow only to maturity and then are harvested. Preliminary analysis using our model suggests that Alberta's overmature/old-growth timber supplies would be exhausted by 2042—in roughly 41 years—if historical cumulative impact patterns continue.

This may surprise some, but not others. To laypersons, the loss of Alberta's remaining older trees in less than 50 years may seem like an undesirable legacy to leave their grandchildren. To professional foresters it means we have achieved our desired outcome—a managed, long-run-sustained-yield forest, albeit one based on younger age classes with less age diversity. Thus the results for foresters and industry would not come as a surprise since they are managing the productive forest land base as a just-in-time inventory system, similar to agriculture or other inventory system.

The problem with managing forests in this way is that they are continually subject to the risks of natural disturbance and to the uncertainty of impacts of land use. These cumulative impacts may threaten sustained harvesting needed to meet timber volume demands of the existing forestry infrastructure as well as future supply needs. Such sudden shocks to timber-supply flows from a regulated, just-in-time inventory may pose a serious risk to the short- to medium-term viability of some forestry companies whose operations require a continuous supply of mature timber to remain efficient and provide the necessary financial returns on their investments. These shocks ultimately jeopardize the available inventory of mature trees to keep the mills in operation.

Exactly where such risks lie geographically in Alberta is beyond the scope of this analysis; however, future accounts of timber capital could be developed at the forest level, at the forest management agreement (FMA) level, or the firm level. Which companies or forests would be most at risk with a significant decline or collapse in mature timber stock to supply mills is anyone's guess.

Dr. Brad Stelfox has been modeling the cumulative impacts of fire and land use on Alberta Pacific's FMA area and has estimated that their overmature timber supply will be exhausted in 40 to 60 years (compared to our estimate of 42 years remaining at the provincial scale). The lower bound of 40 years assumes no effective fire suppression while the upper bound of 60 years

[p] Strictly speaking, we would break out deciduous and coniferous timber supplies and model their respective depletion of overmature volumes given that they have different maturity thresholds. Our analysis is preliminary, simply to illustrate the potential use of timber resource accounts to develop such "what if" scenarios.

assumes full fire suppression and fast recovery rates from energy sector impacts. Stelfox's ALCES®[29] cumulative impact model can estimate future timber supplies by assessing risks due to fire, oil and gas development and other impacts on the landscape. His model is an ideal framework within which to conduct "what if" scenarios for timber supply at the provincial, forest or firm level. Stelfox's analysis provides a good tool for assessing the potential impacts of various drivers or key impact variables (e.g., fire, logging, level of energy sector development, and regeneration rates for energy sector footprints). The ALCES model empowers foresters and public policy decision makers to assess risk and mitigate against risk given the evidence the model reveals. It points to the need to consider the cumulative impact of both natural and human-related disturbances when developing long-term timber supply strategies.

The key point in our analysis is that while industry can and will likely remain viable despite the loss of overmature/old-growth forest, there is a fundamental ecological cost and potentially ethical dilemma that society faces if such a significant amount of Alberta's natural ecosystem is being affected. Despite the risk to industry, firms will respond by remaining flexible and making necessary mid-course corrections—where flexibility allows on the land base and given the constraints of tenure systems and property rights. Technological innovations will also enable us to respond in the medium term to timber capital risks.

The move to a fully regulated, productive forest management regime representing roughly 26 percent of Alberta's 66-million hectare land base will have a cost associated with restructuring of the natural forest. These costs will include losses in biodiversity, age-class diversity and effective species habitat, as well as possible threats to ecosystem health and services. While these costs remain unaccounted-for in monetary terms, they may be seen as regrettable impacts on future generations for short- and medium-term monetary gains.

Another unaccounted-for loss is the qualitative loss—both in monetary and non-monetary terms—of the old-growth trees that could have value for log home construction, veneer logs, aesthetics, as a carbon sink, or other ecosystem values. Also, we know little about the ecosystem service values of a more age-class-diverse forest compared to an even-aged, regulated forest.

Our analysis does not suggest that the loss of mature timber is certain or potentially catastrophic for economic well-being or the prosperity of Alberta's forest industry. Nevertheless, the distinct possibility that Alberta's old-growth forest legacy may be gone in 50 to 60 years should be open for public debate. Is it acceptable for this "cost" of more economic growth and more exports of timber capital to be imposed on future generations? Are there other alternatives to a fully regulated industrial forest management regime? Consider, too, that most of Alberta's timber capital is being exported to the U.S. and other markets for short- to medium-term financial and economic benefits—an amount of timber that far exceeds what is needed to sustain current and future domestic needs of Albertans. How much of our timber capital are Albertans willing to export or forgo exporting to achieve a forest ecosystem that includes old growth?

9.2. Indicator 2: Forest Area

Alberta's total land base is 66.3 million hectares (662,948 km^2), of which 58 percent, or 38.2 million hectares, is forested.[q] Roughly 87 percent of forest land is public, or Crown, land.[30] According to the Alberta GPI forest land accounts (see Table 4) the area of productive forest land in Alberta in 1961 was 18,362,146 hectares and had declined 2.9 percent by 1999 to an estimated 17,825,703 hectares. Thus in 1999 some 17.8 million hectares (or 26 percent of the total forest land base) was considered "productive" stocked, forest land (or "non-reserved, accessible stocked") available for commercial forest harvesting.[31] An additional 2.1 million hectares of the total forest land base is considered productive but is not stocked with growing trees (i.e., "nonstocked forest").

The vast majority of Alberta's forests are part of a great global Boreal forest ecosystem that constitutes one of the world's largest remaining tracts of intact forest. Alberta's forests are divided into six terrestrial ecozones, as shown in Table 6.

Table 6: Alberta Forest Land Ecozones

	thousand hectares	% of total forest land area
Boreal plans	28,689	75%
Taiga plains	5,234	14%
Montane cordillera	2,764	7%
Prairies	706	2%
Taiga shield	430	1%
Boreal shield	391	1%
Total forest area	38,214	

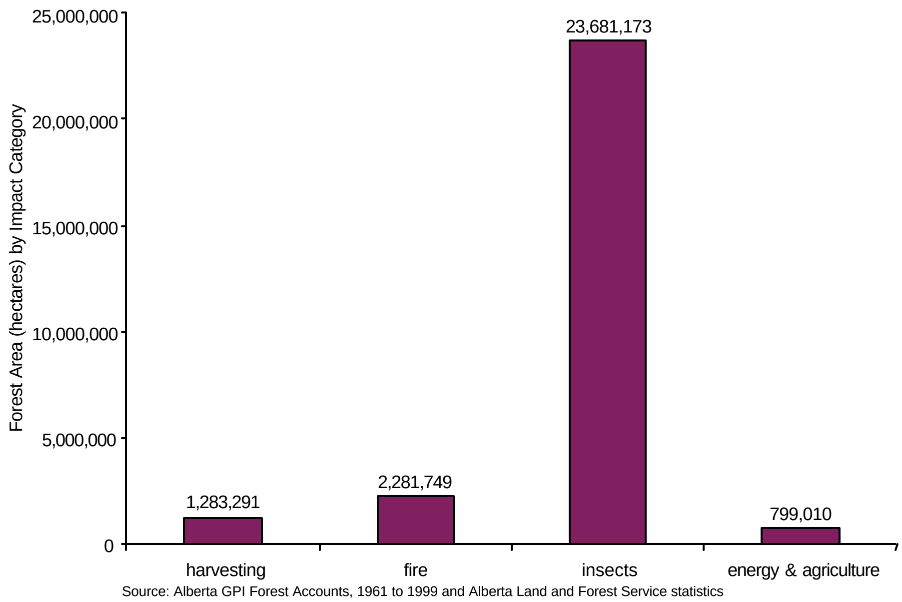
Source: National Forest Database Program

The decline in Alberta's productive forest land base is due to the combined impacts of land use development related to energy, agriculture, mining and other land use activities. Although oil and gas development is arguably a long-term removal of forest for timber management purposes, it is not necessarily a permanent deletion. Also, roads, well sites and seismic lines can be reclaimed in the future and put back to productive forest.

Figure 2 shows the relative impacts between 1961 and 1999 on Alberta's productive forest land. According to Alberta LFS statistics, by the far the greatest impacts on forests are from insects and diseases, with an accumulated impact from 1961 to 1999 of 23,681,173 hectares. This is an extraordinary total since it represents an area greater than the current estimated productive forest land base of 17.8 million hectares. This large figure may be because the same area of forest could be infested repeatedly, resulting in double counting of the same area. Fire ranks as the second largest forest land impact with an accumulated 2,281,749 hectares of productive forest land burned since 1961. However, the impacts of fire, insects and disease do not create a permanent loss of productive forest land base. Timber harvesting has the third largest impact at 1,311,035 hectares over the study period, followed by 830,608 hectares removed due to agriculture, energy development, roads and other linear disturbances. Balancing the reduction in productive forest land due to land use changes has been the reconversion of agricultural land back to forest land, totaling 302,226 hectares since 1961.

[q] The province uses "Green Area" geographic region convention. The Green Area represents 53 percent, or roughly 31,135,000 hectares, of Alberta.

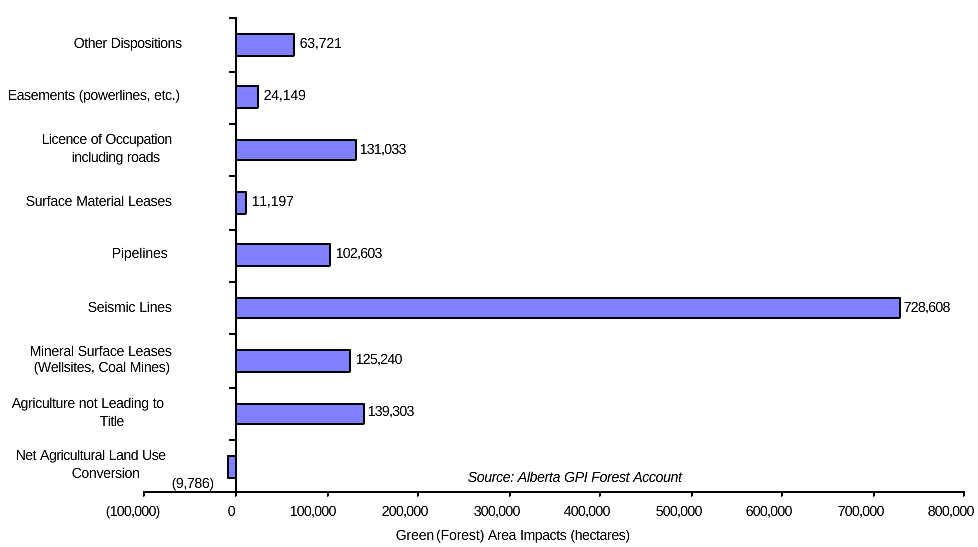
Figure 2: Harvest, Fire, Insect and Deforestation (Oil, Gas, Roads, Agriculture) Impacts on Alberta Productive Forest Land, 1961 to 1999 Accumulated



The accumulated area that has been deforested due to roads, energy and agriculture development since 1961 is equivalent to 63 percent of the total harvested area. Energy and agricultural development continue to have a profound impact on Alberta's forest land, both in terms of commercial timber supplies and in terms of forest fragmentation and degradation of forest ecosystem health. These issues are dealt with later in this report.

Seismic lines used for oil and gas exploration and development have had the greatest impact of all, followed by agricultural leases not leading to title (e.g., grazing leases), roads (licence of occupation), wellsites and mineral leases. Figure 3 shows the accumulated impact of these deforestation activities from 1961 to 1999.

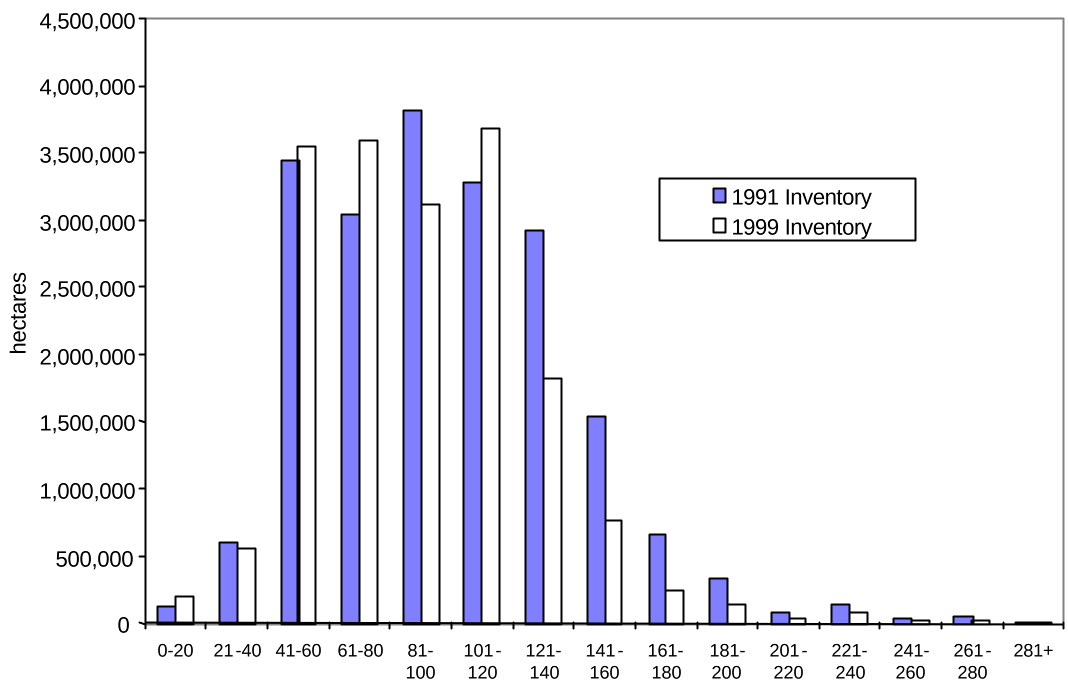
Figure 3: Deforestation and Land Use Impacts by Type, Total Area Impacted on the Total (Green) Forest Land Base, 1961 to 1999



9.3. Indicator 3: Forest Age-Class Distribution

Alberta's forests are getting younger as older trees are harvested first and the forest is losing its age-class diversity. What this means for future forest ecosystem health and integrity is not known, but clearly a more diverse age-class forest is more desirable state. Figure 4 is a rough comparison of the distribution of Alberta's timber inventory by age class and shows a shift from older to younger age classes between 1991 and 1999 on provincial public forest land. This portrait should be interpreted with some caution. Unfortunately the Alberta Land and Forest Service does not have a longitudinal portrait of changes in age-class distribution over time.[32] Even this comparison of 1991 and 1999 requires a cautionary note that the two years may not be directly comparable as the total reported area differs between the two data sets. This is due partly to incomparability of Alberta's three forest inventories beginning with Phase 1 Inventory in 1964.[33]

Figure 4: Alberta Timber Age-Class Distribution, 1991 to 1999



Source: Alberta Land and Forest Service

Notwithstanding the data challenges, the data reveal that the area of mature forest declined by nearly 30 percent from 1991 to 1999 based on Alberta Forest Service timber inventory updates for those two years. Factors that reduce older age classes include harvesting, disease, catastrophic fires (e.g., in 1995 and 1998), and the impacts of energy development activities. And liquidating the oldest-age classes of timber capital has undoubtedly had some impact. The mature age classes are critical to supplying Alberta's forest industry with a sustainable supply of timber capital. While harvesting may be reducing the oldest age class profile, it is likely that fire suppression has actually saved some of this timber. Tracking changes in the age-class distribution over time will be critical to assessing the risk to Alberta's forest industry from catastrophic and sudden timber capital losses due to fire, particularly at the Forest Management Unit or regional scale.

Roughly 57 percent of Alberta's forests were in mature age classes while 44 percent were in an immature or non-merchantable state (less than 80 years); only 3.1 percent of old-growth forest stands (160 years and older) remain. With the exception of the 101- to 120-year age class (which increased in area), all other mature age classes are in decline and will continue as harvesting of older age classes occurs and as industrial and natural disturbances reduce this population. Protecting the health and vitality of the 60- to 100-year age classes will be critical to ensure the long-term sustainability of Alberta's timber capital for forest industry use over the next 25 years.

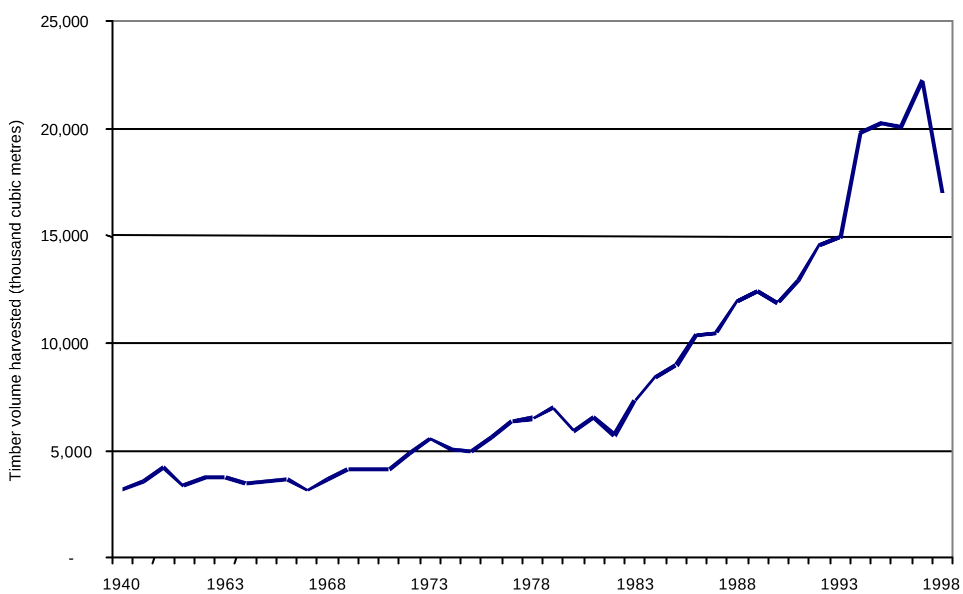
The development of timber capital accounts at the forest management unit level or by forest management agreement area would provide evidence to assess the risks to sustained timber supply in the short, medium and long term. Timber Sustainability Indices at the forest management level would also provide an indicator of sustainability.

The completion of the Alberta Vegetation Inventory (AVI) to replace the 1984 Phase 3 Inventory will provide more accurate information. Therefore, a more accurate representation of the current age class distribution should be derived from the individual forest management unit (FMU) or Forest Management Agreement (FMA) level AVI where it has been completed. However, until such time as the AVI is completed for all of the productive forest land in the province, developing a composite provincial age class distribution combining the available AVI data and extracting the remaining area with Phase 3 data would be a significant task.[34]

9.4. Indicator 4: Harvesting (Logging) Trends

Until about 1982, timber harvests averaged approximately 4.6 million cubic metres per year, but by 1997 timber harvest volumes had multiplied almost five times, to over 22 million cubic metres annually (see Figure 5). This dramatic increase was due to massive expansion of Alberta's forest industry in the mid-1980s, with the burgeoning pulp and paper industry and panelboard (OSB) production using what was once considered a weed tree, aspen.

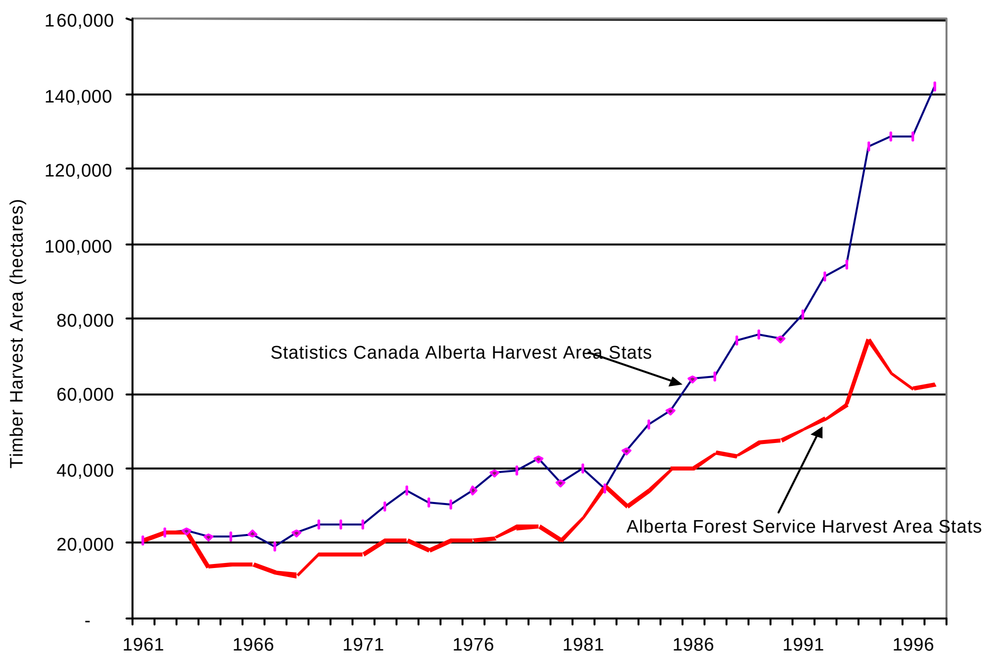
Figure 5: Timber Harvest Volumes, 1961 to 1999



Source: National Forest Database Project, CCFM

Figure 6 shows a significant discrepancy between the Alberta LFS harvest area figures and those derived by Statistics Canada (*Econnections*).[35] Statistics Canada harvest area figures are estimated by converting roundwood timber input reported by Alberta forest industry firms to an area of timber-harvest equivalent (using an average yield or stocking figure for Alberta forest land). We believe that Statistics Canada's average yield numbers (162 m^3/ha), based on dividing harvest volumes by harvest area, from 1961 to 1999, are reasonable. Comparing LFS and Statistics Canada harvest volume figures reveals the same data time series, so the problem is not with volume figures. If we apply the Statistics Canada volume-harvest-to-area-harvest calculation to LFS harvest volume and harvest area figures between 1961 and 1999 we get an average yield of 256 m^3/ha, or 1.57 times the Statistics Canada figure. The LFS yield figures do not appear to reconcile with LFS timber inventory tables for 1999, which show average yields for all age classes of only 106 m^3/ha and only 148 m^3/ha for mature timber. One explanation for the growing discrepancy between Statistics Canada and LFS harvest area figures is that the LFS harvest figures do not include harvesting from private forest land, although Alberta LFS disagrees with this assumption.[36] Whether the gap can be explained by the unaccounted private forest land harvest area remains to be examined, however, the area is apparently significant. For example, the difference of 79,362 hectares of harvest area seen by comparing the 1997 Statistics Canada harvest area (142,100 hectares) with 1997 LFS harvest area (62,738 hectares) suggests a significant policy issue if in fact the difference is due to logging of private forest lands.

Figure 6: Discrepancy Between Statistics Canada Harvest Area and Alberta Forest Service Reported Harvest Area



While public forest land may be managed carefully, there are no such guarantees on private forest land. If Alberta's forest industry is this dependent on private forest timber capital, then there should be considerable concern about future sustainable timber supplies to meet current forest industry demand and capacity. This issue, combined with the continued impact of oil and gas development on the forest land base provides little comfort about the long-term sustainability of timber capital for the existing Alberta forest industry.

9.5. Indicator 5: Forest Fragmentation and Cumulative Impacts of Development

Fragmentation of a forest ecosystem due to linear disturbances has a measurable and visual impact on the integrity of the forest ecosystem, even if the impacts are difficult to assess. A certain amount of fragmentation may benefit some species of wildlife and be detrimental to others. The key questions concerning forest ecosystem fragmentation include: (1) how permanent are the impacts of linear disturbance on ecosystem services, wildlife and natural capital flows; and (2) how does the type of fragmentation affect Alberta species that may be adapted to natural disturbance from fire effects? These questions require more research and measurement work.

Using our Alberta forest resource accounts, we have updated the World Resources Institute's forest fragmentation analysis. We estimate that over 90 percent of Alberta's productive forested area has been fragmented due to roads, seismic lines, wellsites, pipelines, powerlines and other land use impacts. For example, by 1999 an estimated 199,025 oil and gas wells and 1.5 to 1.8 million kilometres of seismic lines crisscrossed Alberta's forests, with more linear disturbance expected with new oil and gas developments.[37]

The World Resources Institute's report *Canada's Forests at a Crossroads* (2000) estimated that in 1997, 83 percent of Alberta's forests were fragmented by roads, forestry, energy industry and agricultural development, and other access routes. This places Alberta second in Canada in terms of forest fragmentation, after New Brunswick with 88 percent of their forests accessed and fragmented. Fragmentation is defined in the WRI study as any forest area with linear access densities greater than 9.0 square kilometres. Using the WRI 1997 estimate and definition of fragmentation as a starting point, we then backcast the trends from 1961 to 1997 and from 1998 to 1999 based on linear disturbance data in the Alberta GPI forest account. Looking forward to 1999, we estimate that 90.5 percent of Alberta's forest area (outside of national parks) is fragmented. Put another way, less than 10 percent of Alberta's forests remain as wilderness. The WRI estimates are consistent with those by Richard Thomas in a study he completed for Alberta Environmental Protection in 1998; Thomas estimated that only 14 percent of Alberta's Boreal forest ecosystem had not been fragmented by roads, seismic lines, pipelines or other linear and land use disturbance, while less than one percent of the Foothills forest ecosystem remained unfragmented.

The Thomas report notes that the deforestation of Alberta's forests is comparable to the historical deforestation of the Amazon rainforest.[r] The report notes that, "Annual deforestation rates in the southern Dry Mixedwood [forest] between 1949/50 and 1994/95 averaged 0.91 percent (= 192 km^2/yr), which is proportionally higher than the annual rate (0.87 percent) reported for Amazonia during 1975-1988. The rate of forest loss in the northern Dry Mixedwood between 1961 and 1986 was 0.81 percent/yr."[38]

Thomas found that Alberta's forests are significantly fragmented by seismic lines, pipelines, wellsites, harvest blocks and other land use disturbances. According to recent studies an estimated 14 percent of Alberta's Boreal Forest natural region (346,964 sq km, or 63 percent of Alberta's Green Area of forest land base, or 52.3 percent of Alberta's land base[39]) and less than one percent of the Foothills natural region (94,790 sq km, or 14.3 percent of Alberta's total land base) remain in an unfragmented or wilderness condition. Combining Thomas's two

[r] Alberta LFS argues that comparing Alberta with the Amazon is unfair since the loss of Amazon rainforest is considered a permanent loss of forest while the fragmentation of Alberta's forest land is considered acceptable, since Alberta forests are already adapted to some level of natural disturbance.

fragmentation estimates for the Boreal and Foothills forests yields a composite fragmentation estimate of 9.5 percent of these forest ecosystems, which represents over 77 percent of the total forest land base. Thus the combined Thomas figure of 9.5 percent unfragmented Boreal-Foothills forests is not entirely comparable with the WRI estimate of 17 percent of total forest area. The differences are due largely to differences in definition of fragmentation parameters. Regardless, the impacts are real and severe.

The story of forest fragmentation and the impacts of 50 years of energy and industrial development in Alberta's forests is best revealed in aerial photographs of the same portion of the Swan Hills forest (Boreal) area, comparing 1949 with 1991 (Figures 7 and 8). The contrast is stark. They show how the area has changed from a roadless wilderness to a strongly fragmented landscape in only 40 years and, as the Thomas report on the state of the Boreal forests states, "to a greater or lesser extent, the same is true for much of the Foothills Region."[40]

It would be instructive to show linear disturbance impacts across the entire forest land base of the province using colours to show the extent of linear disturbance in relationship to forest cover; unfortunately such satellite imagery is not readily publicly available.[s] As with the Swan Hills example, such visual images provide a striking reminder of the physical impact of industrial activity on the landscape. The real and measurable impacts on ecological integrity, ecosystem services, wildlife, long-term climate impacts, and human health are largely undetermined at this stage and require further study.

The development of Alberta's energy resources (oil, gas and coal) has had as much of a cumulative impact on the forest as timber harvesting. A total of 1,311,035 hectares were harvested between 1961 and 1999, roughly seven percent of the total productive forest area in 1999 (an estimated 17.83 million hectares). By contrast, 830,608 hectares of Alberta's productive forest area has been deforested or affected by energy and agricultural development—about 63.3 percent of the total area harvested. Natural disturbances have had the most profound impact on forests with 2,281,749 hectares (12.8 percent of productive forest land) burned between 1961 and 1999.

The cumulative impact of all land use is most poignantly portrayed by comparing the Alberta Green Area Map (Figure 9) with a map of forest fragmentation produced by the World Resources Institute using aerial imagery (Figure 10). Figure 9 shows the extent of Alberta's total forest area while Figure 10 shows the remaining area of forest land with access densities of less than 9.0 km^2 (i.e., areas that remain roadless and unfragmented) in Alberta and northeastern British Columbia. The white area in Figure 10 is forest land that is not fragmented (that is, areas that are less than 9.0 km^2 in size) while the green squares (polygons) are areas that retain their integrity (i.e., more than a contiguous 9.0 km^2) or are not accessed and fragmented by linear disturbance. Figure 11 shows the various degrees of access densities in the forests of the Alberta and northeastern British Columbia portion of the Western Canadian Sedimentary Basin. This information led the World Resources Institute to conclude that roughly 83 percent of Alberta's forests were fully accessible through various linear disturbance corridor fragmentation.

[s] We find it unfortunate and ironic that satellite or aerial images of the total forest land base showing the extent of industrial development impacts are not readily available. We can only imagine the reaction of Albertans to contrasting images of 1960 (before) and 2000 (after 40 years of economic growth) similar to the Swan Hills aerial photos. We would be left asking ourselves whether development at the cost of such forest ecosystem devastation is an acceptable "price" to pay for more development of nonrenewable natural resources.

Figure 7: An Area of the Swan Hills Forest in 1949

Figure 8: The Same Area of Swan Hills Forest in 1991

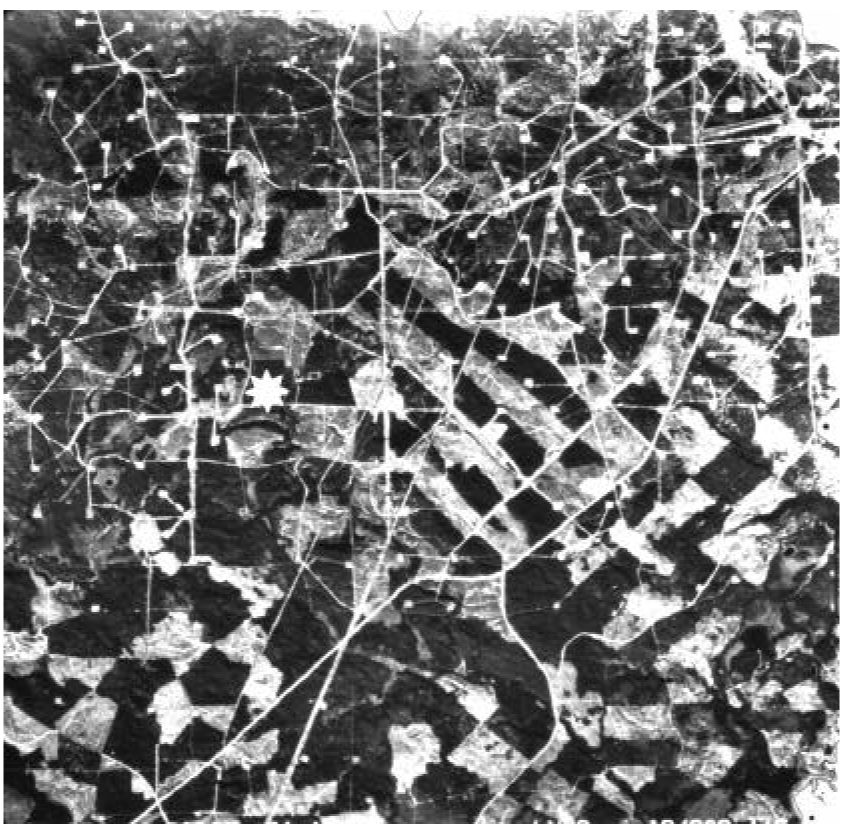


Figure 9: Alberta's Green Area Map

Source: http://www.gov.ab.ca/env/forests/fmd/timber/map1.html

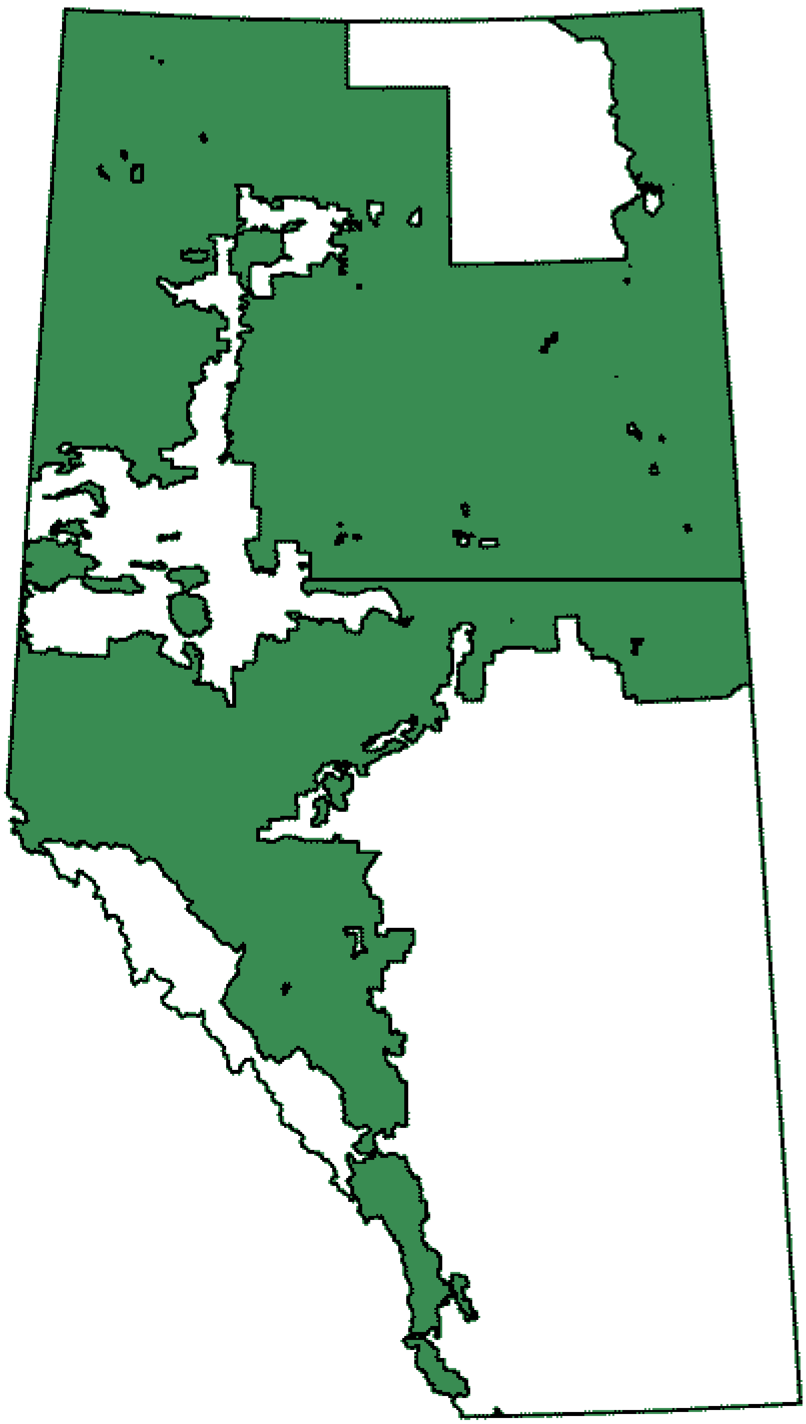
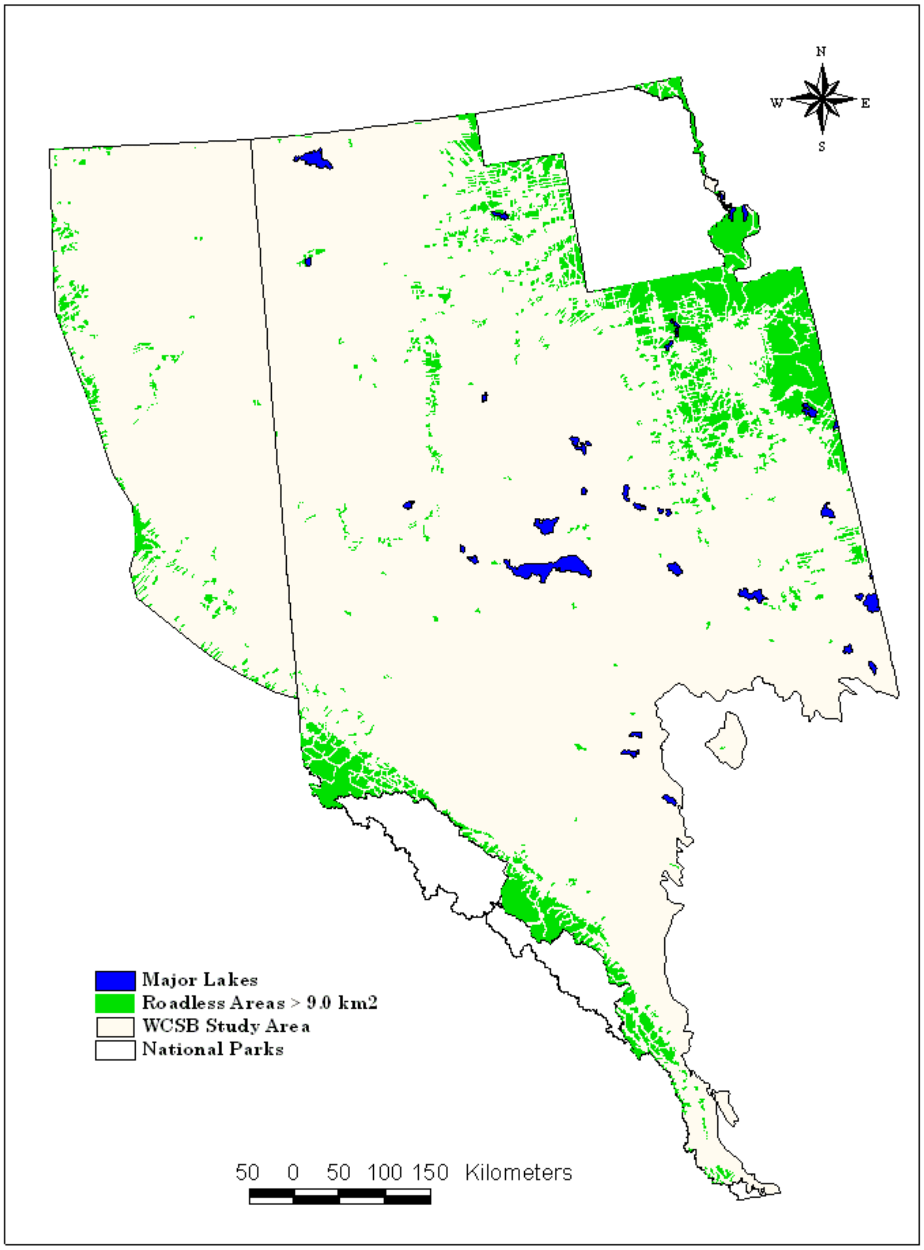
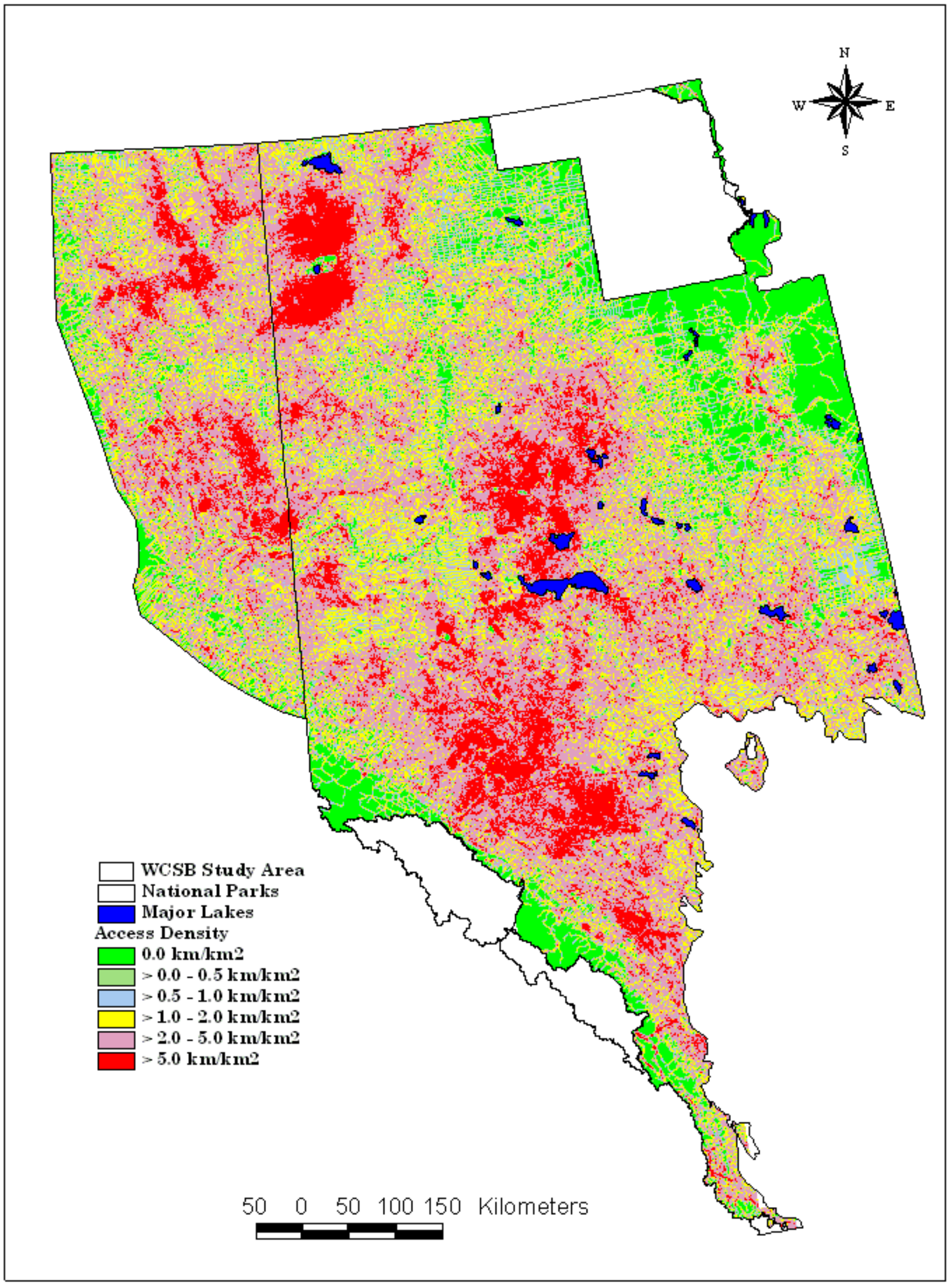


Figure 10: Remaining Areas with Access Densities >9.0 km^2 in the Forest of the Alberta and Northeastern British Columbia Portion of the Western Canadian Sedimentary Basin



Source: World Resources Institute. 2000. *Canada's Forests at a Crossroads: An Assessment in the Year 2000*. A Global Forest Watch Canada Report, Washington, D.C.

Figure 11: Access Densities in the Forest of the Alberta and Northeastern British Columbia Portion of the Western Canadian Sedimentary Basin



Source: World Resources Institute. 2000. *Canada's Forests at a Crossroads: An Assessment in the Year 2000*. A Global Forest Watch Canada Report, Washington, D.C.

The loss of ecological integrity and wilderness due to fragmentation is largely unknown and uncalculated, though the losses do represent liabilities for wildlife, climate change, watershed and water quality and other ecosystem services.

The combined impacts of human activities on Alberta's forest land base have left primary forest natural regions, the Boreal Forest region and Foothills Forest region, in a seriously fragmented state. The cumulative impacts of roads, seismic lines, pipelines, wellsites, grazing leases and other disturbances have left only nine percent of Boreal Forest and less than one percent of Alberta's Foothills forest region in what might be called "wilderness" or unfragmented condition.[41] According to the Global Forest Watch report, "Of the 10 major forest types found within Canada, two have lost about 60 percent of their forest cover. Seven of these 10 have more than half of their remaining forest area fragmented by access routes.[42] Fragmentation is especially important for wildlife, as it improves access for predators, both wild and human. Habitat fragmentation has been cited as "the most serious threat to biological diversity" and "the primary cause of the present extinction crisis."[43]

Thomas examined the various causes of this fragmentation. He found that by mid-1997, 88,588 wells had been drilled in the Boreal Forest region (34.8 percent of all wells drilled in Alberta) and there was an average of one well every 3.92 square kilometres.[44] Using a conservative estimate that each wellsite is one hectare in size, he calculated that a total area of at least 885 km^2 (9.5 townships) had been cleared for wellsites in the region. By the end of 1998, there were an estimated 93,731 wells in the Boreal Forest region (an increase of 5.8 percent in 18 months), giving a total cleared area of 937 km^2.

Each wellsite needs an access road, which further increases fragmentation. There are no accurate data concerning the total length of this road network, but Thomas estimated that the roads had a total length of nearly 142,000 km. Taking an average access road width of 15 metres, he estimated 2,126 sq km were occupied by the actual roadbeds (22.8 townships) by mid-1997. Given the 5.8-percent increase in the number of wells by the end of 1998, the length of access roads could have increased to 150,236 km by the end of 1998, while the area occupied by access roads could have increased by a further 123 sq km, for a total of 2,249 sq km.

Seismic lines are the greatest single cause of fragmentation in the Boreal Forest. Lee and Timoney[45] estimated the total length of seismic lines at 1.5 to 1.8 million kilometres. Using Thomas's estimate that the Boreal Forest region represents 63 percent of the Green Area of the province and an average cutline is 8 metres wide, over 5,000 sq km have been cleared for cutlines since 1979. Seismic lines are no longer 8 metres in width having been reduced in many cases to less than 1.5 metres and in other cases completely avoided. Future linear disturbance accounting within the GPI forest accounts will reflect these positive impacts of smaller seismic widths. Many seismic lines will reforest naturally if they are not recut.

Pipelines cause further fragmentation. The cumulative length of pipelines constructed in Alberta (to the end of 1999) is 276,550 km, of which over 241,000 are still operational.[46] Working from data used by Thomas, we estimate that approximately one-third of pipelines are located in the Boreal forest. This means that by the end of 1999, about 88,496 km of pipeline had been constructed in the boreal forest, excluding the interprovincial and international pipelines that are under the jurisdiction of the National Energy Board. Assuming a conservative average corridor width of 15 metres, at least 1,327 sq km had been cleared for pipelines in the Boreal Forest Natural Region.

Thomas's figures are based on data to December 1996. Alberta Energy and Utility Board (EUB) figures show 51,397 km of pipelines constructed between 1994 and 1997, giving an average of 12,849 km per year. Deducting this from the EUB's 1997 figure of 240,644 km gives a total length of pipelines in Alberta in 1996 of 227,795 km. Thomas estimates that 73,103 km of pipelines were located in the Boreal Forest by the end of 1996, which is 32 percent of the Alberta total. Thomas estimated that 34.8 percent of wells were drilled in the Boreal Forest region. Taking the average of 32 percent and 34.8 percent means that an estimated 33.4 percent or one-third of Alberta's Boreal Forest has endured energy linear disturbance.[47]

The figures Thomas used for calculating the area occupied by wellsites, access roads and seismic lines are quite conservative and smaller than figures used in a report prepared for the Alberta government in 1981 by Hardy Associates, as shown in the table below.[48]

Table 7: Comparison of Estimated Area Taken by Energy Projects

	Hardy, 1981	Thomas, 1998
Well site area	1.6 ha (4 acres)	1 ha (2.5 acres)
Access road width	20 metres (66 ft)	15 metres (49 feet)
Seismic line width	7.6 metres (25 ft)	8 metres (2.5 feet)

The 1981 study, which was based on a sample of eight percent of townships in the Green Area of the province, adjusted to provide an 80-percent confidence limit for the results, found that at the end of December 1979, 314,133 hectares (or one percent of the Green Area) were disturbed by energy exploration and development.[49] Of that, 52 percent was within areas mapped as productive forest. About 70 percent of the areal disturbance (219,071 ha) was due to seismic lines, 10.2 percent to oil and gas roads and wellsites (32,152 ha), 10 percent to multipurpose rights-of-way, 4.8 percent to power lines and pipelines, and the remaining five percent to coal mines, oilsands, miscellaneous oil and gas areas, and gas plants.[50]

The Hardy study drew attention to a 1979 study by the Environment Council of Alberta[51] that was based on data from the files at Alberta Environment. This indicated that the area affected by seismic activity was 45 percent larger than in the Hardy survey. Recalculating the ECA data, to update it for comparison with the survey figures, Hardy estimated the total area affected by seismic activity was 783,000 acres (317,000 ha) in the ECA study, compared with 541,451 acres (219,000 ha) in the Hardy survey.

The Hardy study reported that, "While the amount of previous forest clearing for energy development is significant (one percent of total area), it is not cause for alarm. Only about half of this clearing has occurred on productive forest." It asserted that, "Government is not complacent about this clearing, and continues attempts to minimize depletions and their long term effects."[52]

It seems that the government has not been very effective in reducing deletions and their long-term effects. Twenty years later, Thomas noted that oil and gas development causes serious problems within the forest area.[53] Wildlife habitat is destroyed and fragmented, and animals themselves are killed in collisions with road traffic or removed from industry sites due to safety concerns. Increased sedimentation can damage fish habitat during construction and use of roads and pipelines. And air and land pollution arise from emissions from flaring, leaks from pipelines and wellsite blowouts or spills from poor management of oilfield wastes.

In 1998, there were 885 pipeline failures in Alberta.[54] If the distribution of failures were based on the distribution of pipelines across the province, nearly 300[t] would have occurred in the Boreal Forest natural region. Two-thirds of these failures were due to corrosion, which, as pipelines age, is an increasing cause of failure. In the same period, there were 1,354 liquid releases (including water and oil) from pipelines, wells, and other oil and gas sources, which could mean over 400 occurred in the supposedly "natural" Boreal Forest region.

Fragmentation in the Foothills Natural Region of Alberta has also been documented.[55] This region, as its name implies, extends from south to north along the eastern slopes of the Rocky Mountains and covers 14.3 percent of the total area of the province. It is intermediate in character between the Boreal and Rocky Mountain Natural Regions, containing extensive mixed forests with white spruce and lodgepole pine as major species, according to location. Logging and the energy industry have affected almost the entire region, seriously fragmenting habitat.

The Foothills study of the impact of oil and gas lines showed an average of one well every 4.1 sq km and only 91 of the 1,297 townships (7 percent) in the Foothills Natural Region showed no evidence of logging or well sites.[56] Of these 91 townships, only five were not dissected by pipeline rights of way, transmission lines or more than 5 km of seismic lines, and could be regarded as "wilderness" townships. Therefore only 0.4 percent of the Foothills Natural Region might be considered as wilderness or unfragmented. Since some of the air photos on which the assessment was based date from 1988, the status of these remaining townships may now have changed.

Other aspects of energy exploration and extraction also have impacts. "Traffic and noise related to the construction and use of pipelines, roads, compressor stations, cutlines and gas plants, plus well drilling and servicing activity results in the disturbance an displacement of wildlife. In addition, acoustic pollution (from explosions, bulldozers and other vehicles) during seismic exploration—especially heliborne seismic programs—stresses wildlife and can disrupt their normal behavioural patterns."[57] The same report cites studies from various locations (not necessarily within the Alberta Foothills) that show how elk have abandoned traditional rutting and calving areas; mountain goat numbers have declined; moose have moved away from wellsite areas; and bighorn sheep have abandoned parts of their range due to seismic activity. While one activity may not appear too serious, the cumulative impact of the various activities is significant. Indeed, the remaining natural habitat within the Foothills natural region as a whole has, on average, been moderately to seriously compromised. Creation of an extensive network of access corridors throughout the region—principally by the oil and gas and forestry industries—is considered to be the single most significant factor contributing to this loss. In some cases, clearings (wellsites and cutblocks) may benefit certain wildlife species such as ungulates (e.g., moose, mountain sheep) and bears.[58]

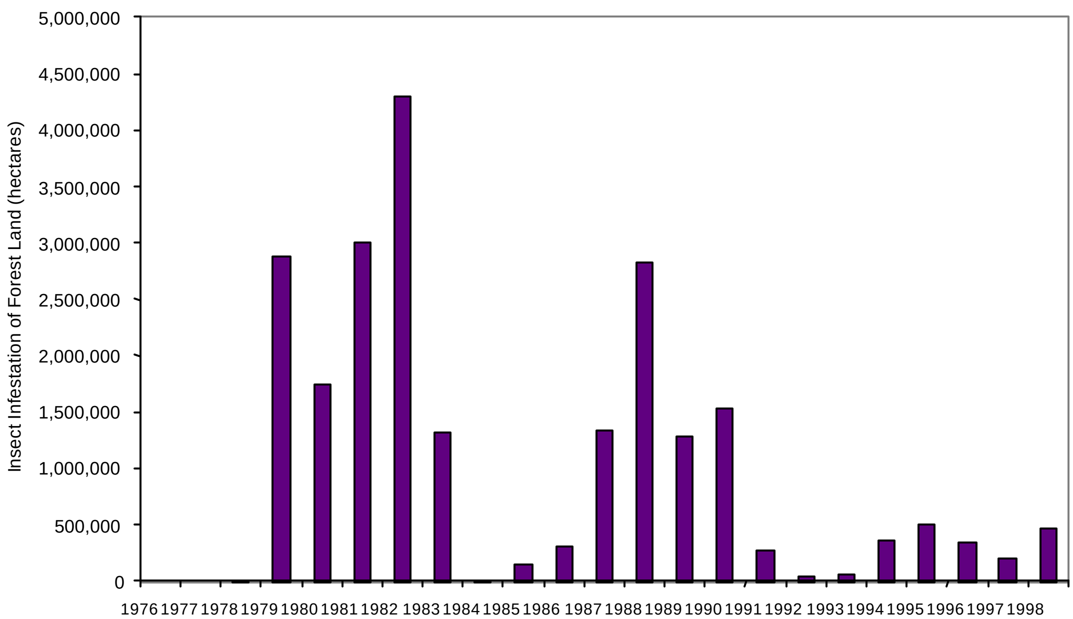
[t] Estimate is 885 x 32% = 283.

9.6. Indicator 6: Insect Infestation Trends

According to Alberta LFS statistics, insects and diseases have had the greatest impact of all natural and human disturbances in Alberta's forests. Between 1961 and 1999, an estimated 23,681,173 hectares of productive forest land in the Green Area of Alberta suffered insect infestations or disease (see Table 4 and Figure 12). This represents an area greater than the estimated balance of productive forest land in 1999. The impact of insects and disease eclipses harvesting and fire impacts by a significant margin.

Figure 12 shows a general moderation in area infested in the latter part of the 1990s after major outbreaks from 1979 to 1983 and then again from 1987 to 1990. Estimates of infested areas in the distant past (before the 1950s) may not have been that accurate because of the limited technology and accessibility challenges, according to Alberta LFS.[59] The history of the Boreal Forest and Foothills Forest Region shows periodic outbreaks of insect pests. According to the LFS there are some indications that the frequency of outbreaks of some major pests, such as the spruce budworm, may have increased during the past three centuries. Even these indications are open to question because they are based on dendrochronological data. According to the LFS, other outbreaks of pests such as the mountain pine beetle are simply nature's way of handling overmature forests.

Figure 12: Insect Infestation



Source: National Forestry Data base. Table "Area within which moderate to severe defoliation occurs including area of beetle-killed trees, by insects and province territory, 1975-1999." http://nfdp.ccfm.org/framesinv_e.htm

The problem with interpreting such figures is that infestations may occur repeatedly over the same hectare of forest land and may not result in mortality or sustained losses in yield. Impacts in terms of reduced growth may not be evident until forests have been reinventoried. According to Alberta LFS,[60] endemic infestations are accounted for in yield curves, whereas areas affected by insect epidemics are removed from the net land base when calculating annual allowable cuts. Nor, according to the LFS, can we assume that rising infestations are a sign of poor forest health.

Problematic for the forest volume accounts is the fact that the area of infestation cannot be equated to a loss of either land base area or standing volume. Growth and yield estimates by the LFS account for past insect and disease activity (i.e., the forests we have today are shaped by past conditions and events—climate, weather, insects, disease, and fire). The LFS adopts a policy where timber harvest activities are directed at areas of epidemic infestation. For example, in the case of the Mountain Pine Beetle infestation in the late 1970s and early 1980s, where the impact is catastrophic, new AACs were developed to account for the shift in age class distribution following the salvage activities.

While not all infestations result in mortality, considerable volumes of affected timber may need to be salvaged to ensure that merchantable timber can be used. The extent of salvaging operations depends on the pest, pest severity and the management objectives for the area infested. The LFS advocates salvaging timber in some stands infested with pest species (such as the pine beetle, spruce beetle and spruce budworm) at epidemic levels. They do not advocate it for large tracts of stands affected by forest tent caterpillar and large aspen tortrix[u] unless these stands are being killed by secondary pests.[61]

Are insect outbreaks related to the stresses of climate change? According to Alberta LFS, "the jury is still out" on whether climatic changes in Alberta's forests have increased infestations.[62] They have noticed that the range of some pest outbreaks, such as those of the forest tent caterpillar, have extended further north than previously recorded. Rising pest populations may or may not be a sign of forest health. Pests are an integral part of the ecosystem and their populations will fluctuate depending on many biotic and abiotic factors. A healthy forest is one that can go through these pest infestations and still sustain its growth. For example, although a few million hectares of forest have been severely defoliated by the large aspen tortrix in northern Alberta, the LFS does not expect this outbreak to have long-term effects on the forest stands; i.e., the forest is still healthy although it has suffered a large pest outbreak.

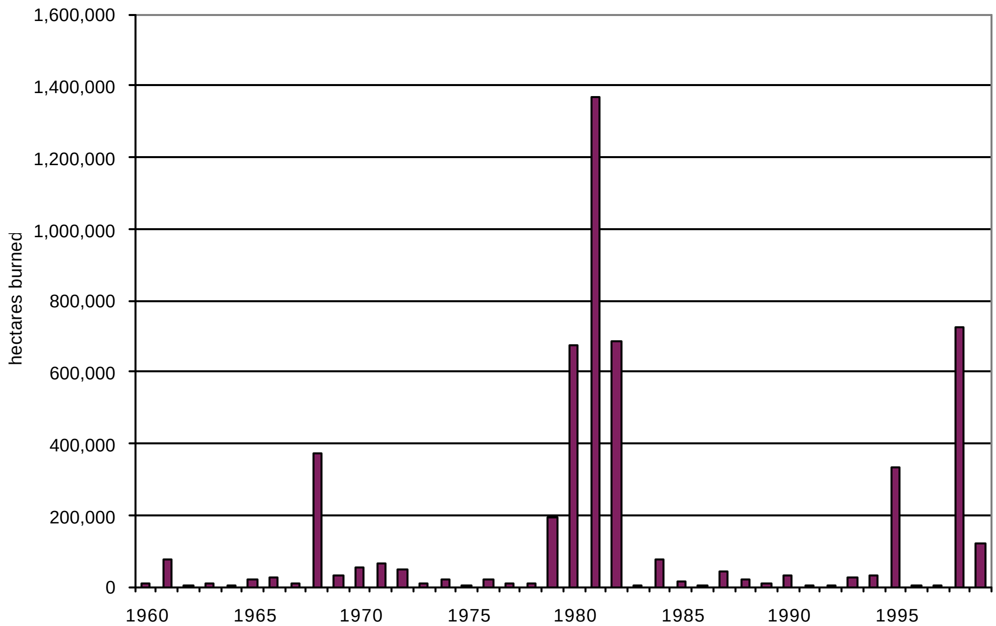
9.7. Indicator 7: Fire

Fire is a natural part of Alberta's forest ecosystem history and has had dramatic impacts on timber supply. The accumulated area of productive forest land burned between 1961 and 1999 is estimated at 2,281,749 hectares, or 167 million cubic metres, more than 174 percent of the total area harvested and 48 percent of the volume harvested.

Major fires have swept the province, primarily in the Boreal Forest and to a lesser degree in the Foothills forest ecosystems. While the Alberta government has spent a great deal of money and effort to manage fire and reduce its effect on timber supply and communities, fire continues to have significant and potentially industry- and life-threatening impacts. Figure 13 shows that despite these public expenditures, fire in the 1990s continued to be a wild card for a sustainable timber supply for Alberta's forest industry, which is now harvesting virtually its entire annual allowable cut. The possible impacts of climate change could further increase the risk of fire. While industry can salvage some fire-killed trees, not all the timber can usually be recovered before it begins to decay, or it may be physically impossible or too costly to access. Fire affects harvest schedules and, in some cases, can be catastrophic for a forestry company should a single fire on its forest management area destroy its allocated timber capital.

[u] The tortrix is a type of moth whose larval forms are pests of aspen.

Figure 13: Area of Productive Forest Land Burned, 1961 to 1999



Source: Alberta Forest Service

9.8. Indicator 8: Biodiversity and Forest Species Health

Forest fragmentation and intrusion of industrial development into Alberta's boreal and other forest ecosystems has dramatically affected both biodiversity and core habitat of forest-dwelling species. Unfortunately, very little is known about the cumulative impacts of timber harvesting and deforestation on wildlife. According to the World Resources Institute, "if current rates of tropical deforestation continue, the number of all forest species could be reduced by 4 to 8 percent."[63] While we cannot directly compare tropical deforestation impacts on biodiversity with Alberta's Boreal Forest deforestation, the portrayal of Alberta's forest fragmentation as the "Amazonia" of the north makes us pause to consider what possible and even latent impacts on species diversity and ecosystem health may exist.

The *Foothills* Report examines the effect of habitat loss and human disturbance on a number of major species.[64] It points out, for example, that the grizzly bear is the "keystone" foothills species and that its current range corresponds closely with the Foothills Natural Region boundary. The *Status of Alberta Wildlife*[65] notes that the grizzly bear is on the "blue" list as a species that may be at risk. The report states that the grizzly is "currently sustaining its population under a very restrictive sport hunting regime. [The] greatest threat is loss and degradation of wilderness habitats through resource extraction and recreational development." The *Foothills* Report[66] cites the *Interagency Grizzly Bear Committee Taskforce Report* for 1994, which recognized that bears need core protected areas, "free of motorized traffic and high levels of human use," but such areas are becoming increasingly scarce.

In 1994, wildlife expert Dr. Brian Horesji stated that, "Alberta's Grizzly Bear population is on the brink of what potentially could prove to be its decline."[67] Observing how human and industrial impacts have accelerated, he says with a great deal of confidence that the situation is more likely worse today than five years ago.[68] He also notes that despite the fact that the bear population is not faring well, there have been no regulatory advances in protecting bear habitat.

The pictures of the "before" and "after" development of a portion of the Swan Hills forest (Figures 7 and 8) provide a visual expression of how such fragmentation might have led to the demise of the Swan Hills Grizzly Bear. According to a study by Nagy and Gunson,[69] Alberta's grizzly population has declined from roughly 6,000 (pre-settlement) to 800, a decline of 85 percent.

The woodland caribou has also been seriously affected by industrial development in the Foothills and Boreal Forest regions. Nationally, the woodland caribou was listed as a threatened species for the first time in 2000.[70] In Alberta, the woodland caribou is listed as an endangered species under the Wildlife Act. The *Status of Wildlife in Alberta* report estimates there are 3,500 animals in the province, with the population stable to declining. According to the Boreal Caribou Research Program, "These caribou are likely to become extirpated in Alberta if the factors causing their reduction in numbers are not reversed."[71]

The *Status of Wildlife in Alberta* 1996 report states there is "Concern over maintenance of old-growth forest to provide critical winter habitat." Citing various authors, the *Foothills Forest* report notes that timber harvesting in west central Alberta is removing large areas of currently occupied caribou habitat and that high levels of industrial and other human activity are a serious threat to the continued survival of the Little Smoky herd. There are two types of woodland caribou, the Mountain eco-type and the Boreal ecotype. All the winter range of the Mountain eco-type and of the Little Smoky (Boreal eco-type) herd have been committed for timber harvesting.[72]

Direct loss of habitat is one problem, but the impact of human activity is far greater than the actual area lost. Caribou avoid human developments by up to one kilometre for wells and 250 metres for roads and seismic lines, according to one study.[73] While roads form something of a barrier to caribou movement, this does not appear to be the case with seismic lines. However, other research has shown that caribou are subject to greater wolf predation close to linear corridors, such as seismic lines.[74] This study concluded "…increased industrial activity in and near caribou range could have a significant effect on caribou population dynamics by increasing predation."

Attention here has focused on the grizzly bear and woodland caribou, as these are "keystone" species. If there is sufficient habitat for these larger mammals to flourish, other species will probably be safe. When habitat for these so-called "umbrella" species is threatened, it probably means that the viability of other smaller species will be at risk in the future. However, we also lack accurate data about the real impacts on other keystone species such as moose and black bear, but that information vacuum has not deterred further intrusion into the forest. Brian Horesji suggests that an index of core habitat effectiveness be developed that measures the condition of core habitat for any given wildlife species. Because the impacts of fragmentation and forest disturbance will vary, a total wildlife species habitat systems approach must be taken that considers the tradeoffs between species—comparing, for example, those that may benefit from more forest edge and those that could be affected negatively by any anthropogenic disturbance of habitat.

The Alberta Natural Heritage Information Centre, set up in 1996, is compiling a geographic database of elements of conservation concern, including plants, plant communities, animals and landforms, based primarily on literature studies. This information provides a useful baseline, but the Centre does not have resources to systematically verify whether species are still to be found in the recorded locations.

9.9. Indicator 9: Reforestation

To maintain a sustainable supply of timber, investment in reforestation is needed. If the reforestation investment fails to provide new timber capital growing stock for future harvest, sustainability of renewable capital will be jeopardized, although the forest will grow back if left alone.

Based on the Alberta LFS "Stocking Inventory" table,[v] roughly 324,994 hectares of forest land are designated "understocked"[75] after harvesting of a total 972,226 hectares between 1975 and 1998. This means that about 33 percent of the total forest area harvested since 1975 remains as a reforestation liability. However, these figures should not be misinterpreted to suggest that a reforestation crisis exists. Rather, the figures simply suggest that of the area harvested over the past 10 to 15 years, some has not been given a clean bill of health (i.e., it is not "fully stocked"). For example, the 1995 Alberta timber resource accounts[76] showed that roughly 97 percent of the area harvested between 1964 and 1981 was considered successfully restocked with growing seedlings, based on the old reforestation standard. Nevertheless, these understocked forest lands should be identified as a "liability" on the timber capital accounts of the province and should be removed when they are deemed "stocked."

Ensuring the success of reforestation is even more important given the evidence presented by the TSI calculations that Alberta's forests (from a total timber supply) may be unsustainable at current levels of harvest, land use impacts and fire, should these impacts continue. Regular monitoring of reforestation performance will be critical to ensuring sustainable supplies of timber. We also note that these figures do not account for the reforestation rate failure on areas affected by fire, insects, and industrial developments.

9.10. Indicator 10: Watershed Development

Forest cover helps to maintain clean water supplies by filtering water and reducing soil erosion and sedimentation.[77] Deforestation, broadly defined as including harvesting and land use development, roads and other linear disturbances, undermines these natural processes. The World Resources Institute says that nearly 30 percent of the world's major watersheds have lost more than three-quarters of their original forest cover.[78] According to the Alberta LFS, Canadian Forest Service studies indicate that the "ideal" watersheds have a certain level of disturbance to maximize water retention.[79]

Most of Alberta's forested watersheds (except for portions of the northeast quadrant of the province) are over 50 percent developed according to Global Forest Watch Canada's Report.[80] This report notes that some human development is evident in 95 percent of Canada's forested watersheds. This is consistent with estimates of high fragmentation of the forest ecosystems. Watersheds provide a range of critical ecosystem services including maintenance of water flow, protection against soil erosion, and habitat for aquatic species. The absence of development in forested watersheds would serve as an indicator of the integrity and maximization of services from watersheds.

The full and long-term ecological and economic impacts of development and deforestation of Alberta's critical forest watersheds are largely unknown and unaccounted-for, based on our preliminary analysis. This area should receive greater attention in future GPI work, given the growing importance of the value of water in Canada and internationally.

[v] The " Alberta Forest Service Stocking Inventory" table for Status Year 1998 was provided by the Alberta Land and Forest Service and shows the area of forest land that has been restocked/regenerated and that which remains not-satisfactorily restocked (NSR) in Alberta's Green Area forest lands from 1975-1998.

9.11. Indicator 11: Carbon Sequestration

According to the World Resources Institute, forest vegetation and soils hold almost 40 percent of all carbon stored in terrestrial ecosystems.[81] WRI reports that forest regrowth in the northern hemisphere absorbs carbon dioxide from the atmosphere, currently creating a "net sink" whereby absorption rates exceed respiration rates. Methods for estimating the stock and flow of carbon in forest biomass, soils and other vegetation are emerging through various national and international carbon budgeting research. Young trees generally grow faster than older trees and thus naturally sequester more carbon per unit of volume growth; standing volumes of old-growth timber do nevertheless serve as important carbon sinks. This preliminary treatment does not delve into the details of carbon sequestration and sinks by forests, although carbon sequestration issues are addressed in Alberta GPI Report #26 *Carbon Budget*.

Canada's boreal forests play a critical role in fixing carbon. Boreal forests in general dominate the dynamics of the terrestrial carbon cycle[82] and account for some 50 percent of the natural exchange of carbon dioxide (Maini 1994).[83] They act as massive, net carbon sinks or storage reservoirs. Earlier estimates by van Kooten et. al. (1992)[84] indicate that 97.7 million tonnes (megatonnes, or Mt) of carbon are sequestered each year, or roughly 62 percent of the total carbon sequestered by all Canadian forests.

A carbon budget account has been developed in the Alberta GPI Accounts; it profiles in more detail the role of forests and peatlands as carbon sinks and their capacity to absorb carbon on an annual basis. The amount of carbon sequestered by Alberta's forests can be estimated by using data on carbon sequestered in a cubic metre of growing timber (green wood), the total area of productive forest land, and the productivity (growth per unit area per annum) of forests.

However, previous preliminary studies on Alberta's carbon account[85,86] show that the capacity of Alberta's forests and peatlands to sequester carbon on an annualized basis is less than 25 percent of the carbon emitted by industry, households, transportation, and other anthropogenic sources. However, this does not imply that forests and peatlands can in fact sequester any human carbon emissions since forests are likely in a natural balance of respiration and photosynthesis. For example, according to a United Nations report by the Intergovernmental Panel on Climate Change, evidence suggests that new forests cannot be relied on as new carbon sinks.[87] The report notes that plans for investing in new forests to sequester additional greenhouse gases will fail to reduce carbon dioxide atmospheric levels because of the inevitability of a saturated carbon balance.

In 1995, the total carbon-equivalent sequestered by Alberta's productive forest land base, which contains the carbon sequestering growing stock of timber, was estimated to be 9.58 Mt of carbon in 1988, declining to roughly 9.55 Mt of carbon in 1995.[w]

[w] The original 1992 estimates estimated annual sequestration rates of 8.17 million tonnes per annum based on a lower growth rate (MAI – mean annual increment) of 1.70 m^3/ha/yr. Based on the recent Timber Supply Status Report prepared by Alberta Environmental Protection, the average provincial MAI has been revised upwards to 1.98 m^3/ha/yr.

10. The Total Economic Benefits and Costs of Forest Capital

To assess the sustainability of all forest capital values, a full cost and benefit analysis of timber and non-timber capital values is required. The original purpose of natural resource accounting is to provide evidence of both physical and economic sustainability of natural capital. The natural resource accounts give policy makers a clearer picture of aggregate welfare of a nation or province than do conventional income accounts and the GDP. Conventional forestry GDP figures, for example, only measure the monetary value of timber harvested and converted to forest products such as lumber, pulp, paper, and panelboard. Resource accounts can be used to examine the relationships between the environment, the economy, and society, thus providing a more holistic view of sustainability. The resource accounts are expressed in physical terms and can be converted to economic or monetary accounts by determining market and non-market values of natural capital and environmental services. The economic accounts for forest capital reveal the monetary value of timber and non-timber capital as well as the estimated economic value of forest ecosystem services. For example, the Alberta GPI forest economic accounts estimate the monetary and socio-economic values of commercial timber harvesting, trapping, and fishing, as well as non-commercial activities such as subsistence resource use by Aboriginal cultures. These non-market services include recreational activities (fishing, hunting, camping) and ecosystem services (carbon sequestration, biodiversity maintenance, water and air regulation).

The monetary valuation of natural capital wealth allows economists to explicitly compare natural capital values with the GDP and the national income accounts. A “green GNP/GDP” can be estimated from the market and non-market values for all forest ecosystems capital and services by adjusting conventional GDP. The GDP is adjusted by first depreciating human-made capital (e.g., plant and equipment), then subtracting the depreciation of natural capital, subtracting the costs of pollution, and finally adding the net value of non-market services. Economists define this net GDP as “green NNP” (Net National Product).[88] The Green NNP is a more comprehensive indicator of forest sustainability because it expresses conventional forestry GDP in terms of a “net forest sustainable income” line by adding unaccounted ecosystem service benefits and deducting ecosystem depreciation costs. If the green NNP falls, this indicates either that a society’s natural capital stock is being depleted or that sustainable income is falling. Such an indicator signals policy makers to consider reinvestment in natural capital and ecosystem services to ensure the sustainability of benefits for future generations.

The forest capital economic accounts can also be useful for budget decision making. They provide evidence of the relative “returns” to timber and non-timber capital. For example, indicators of returns on timber capital include the forestry GDP and forestry employment per cubic metre of wood harvest. This indicator would show whether we are achieving higher socio-economic returns for every tree harvested over time. Another indicator is the economic rent (price of product sold less all costs of production) per cubic metre of wood harvested. Economic rent provides a good estimate of the net return to the province (that is, the people of Alberta) for every tree allocated and harvested by industry. These rents can be compared to the government expenditures on forest management, fire management, and environmental management to determine whether forests allocated for commercial production are providing a net socioeconomic benefit to society.

The valuation of timber capital is particularly useful to:

- assess the total value of Alberta’s timber capital stock;
- assess the amount of economic rent generated by timber harvesting to the province versus other economic benefits derived from forest land;

- assess how much of the economic rent generated by commercial use of the public timber capital is being captured by the government through stumpage fees and other taxes; and
- assess whether the current levels of investment in capital maintenance (i.e., reforestation) are sufficient to sustain the timber capital stock.

Although calculating a green NNP (or GDP) is useful for assessing sustainability of natural capital, accounting for sustainability in physical and qualitative terms is just as relevant and should have equal weighting in sustainability accounting. The Alberta GPI accounts provide such a balance between the importance of physical, qualitative and monetary values of all capital.

In the U.S. GPI accounting methodology (see Appendix D), an estimate of the cost of loss of old-growth forest is made in calculating a net sustainable economic welfare figure. The argument to adjust personal consumption expenditures (the major portion of GDP) for the loss of the value of old-growth forest is made on the basis that:

> *Whenever forest land is cut for timber a range of ecological values are lost, at least until the forest is regenerated to the same age as the stand that has been cut. Even if successful forest management results in full restocking of the same species of timber, the original forest ecosystem may never be renewed. Forest management that focuses primarily on the timber capital may preclude the species complexity and thus the ecosystem services of the original forest. If the forest is cut or regenerated improperly, or if the size of the total cut is sufficient to drive unique species into extinction, the damage from roadbuilding, cutting, and reforestation can be effectively permanent.*
>
> *In theory, an account of value of forest ecosystems should account for the loss of forest ecosystem integrity and ecological services and the cost of unsustainable forest management practices. Conceptually, we focus on two distinct, though interrelated, types of costs associated with roadbuilding and timber harvesting. One is resource loss: the reduction in the amount of timber that can be harvested in the future. The other is ecological: the destruction in species of both plants and animals. Our analysis, however, only focuses on the old growth forest of the Pacific Northwest thus precluding analysis of the loss of ecological services that may have been realized on vast areas of other U.S. forest lands, most of which are now managed and thus no longer in their original or old growth state. We believe our estimates of the loss of forests are conservative. Future accounts should account for the value of sustainable or unsustainable timber capital which is under managed conditions as well as the economic losses of ecological services due to loss of forest ecosystem integrity and biodiversity.*[89]

In the case of the Australian GPI accounts (see Appendix E for details), the value of loss of native forests is included in calculating a net sustainable economic welfare estimates.[90]

> *We take the view that it is inappropriate to place economic values on loss of biodiversity and the losses experienced by people when they see an old-growth forest destroyed. These are ethical issues rather than economic ones. However, since loss of old-growth forests may represent a large impact on well-being, we have decided to include a monetary estimate of the losses for comparison with the GDP measures of changes in welfare. Rather than attempting to value each component of loss, a comprehensive approach to monetary valuation can be obtained by estimates of willingness to pay for preservation of environmental values. (This approach is based on an anthropocentric ethic, one that many would regard as inappropriate.)*

In constructing the Alberta GPI Income statement, we took a more conservative approach than either the U.S. or Australian GPI accounts. The Alberta GPI net sustainable income calculation considers the value of unsustainable use of timber capital and posits a methodological approach to moving towards a full benefit/cost valuation of the loss of forest ecosystem services that results from industrial development and associated forest ecosystem fragmentation. Because the latter estimates are more complex and controversial, we chose simply to provide some discussion of potential methodological approaches and even preliminary estimates of the non-market values of forest ecosystem services.

Our Alberta GPI net sustainable income estimates make two adjustments for unsustainable timber capital consumption. First, we estimated the cost of non-timber forest values lost due to changes (losses) in productive forest land to other land uses. These values ranged from $390,000 (1998$) in 1962 to $23,780,000 (1998$) in 1999. Second, we estimated the cost of unsustainable timber resource use based on the Timber Sustainability Index calculations using opportunity cost values associated with pulp production. These figures range from $240,000 (1998$) in 1962 to $14,600,000 (1998$) in 1999 (see Appendix B for details).

10.1. Accounting for the Economic Sustainability of Forests

The forest industry across Canada is regarded as a significant sector of the nation's economy. This is substantiated by the revenues and jobs provided, as well as by investment and profits gained. However, reports on the economic benefits of the forest industry often misrepresent the net benefits because they do not account for the environmental and social costs of forestry activities. Nor do they account for the public costs or subsidies provided to the forest industry.

Sustainability accounting, as developed by Gale et al. "attempts to capture or describe all of the benefit and costs borne by society as a consequence of a productive activity."[91] This approach to accounting adds in the net social and environmental benefits/costs. The same study identified the following six areas that conventional accounting of industrial forest use excludes:

- direct and indirect subsidies paid by government to forest companies (artificially low domestic log prices, low rates of stumpage, forgone taxes through preferential tax rates, accelerated capital depreciation and tax credits, and direct government support from a range of federal and provincial sources);
- government support through investment;
- social costs of forest industry dependence;
- costs of maintaining public order;
- appropriate reporting of employment levels; and
- costs imposed on First Nations.

In addition, they include the following environmental and natural resource management costs:

- public administration costs;
- environmental externalities;
- environmental restoration;
- depreciation of natural capital;
- neglect of alternative economic uses; and
- second paycheque.

Using these findings, a World Resources Institute Forest Note entitled *Perverse Habits: The G8 and Subsidies that Harm Forests and Economics*, estimated the provincial subsidies and public investments by each province's value of shipments for 1997. B.C.'s estimated provincial subsidies and public investments were used to calculate other value. Forgone and incurred expenditures by the B.C. provincial government in the forest products industry in 1997 included:

- Revenues forgone due to stumpage rates and raw log export ban
- Forest Renewal British Columbia (FRBC) value-added programs
- FRBC communities programs
- FRBC watershed restoration programs
- Other FRBC spending
- Government investment
- Ministry of Employment and Investment, Natural Resources Community Fund
- Public order costs
- First Nations compensation costs
- Public administration costs, Ministry of Forests
- Public administration costs, Ministry of Environment, Lands and Parks

There is no current reliable estimate of what constitutes a perverse subsidy, but the report estimates a scenario where 50 percent of the above expenditures are considered perverse. A detailed analysis of each expenditure is provided.

WRI used the mid-range estimate of B.C.'s estimated provincial subsidies and public investments—$2.51-billion—to calculate a percentage of total value of shipments (10.5 percent of $23.8-billion). Alberta's annual forestry shipments are reported as $4.2-billion (from 1996-97 Public Accounts, Government of Alberta). Therefore, estimated provincial subsidies and public investment amount to $441-million, assuming 10.5 percent of value of shipments. To be more conservative, WRI also estimates at half the B.C. percentage (5.25 percent), in the case that B.C. is unique and the level of support is only half as much in other provinces. In this case, the provincial estimate is $220.5-million.[x]

The same method is used to derive an estimate of federal subsidies and public support. Forgone and incurred expenditures by the Canadian federal government in the forest products industry in 1997 included:

- Federal Income Tax Abatement Program
- Manufacturing and Processing Profits Program
- Reduced Property Taxes Program
- Federal Capital Cost Allowance Program (deferred taxes)
- Tax credits
- Federal Public Administration Costs, Industrial Forestry

All of these expenditures can be considered perverse, according to Gale et al. 1999, insofar as they flow directly or indirectly to industry and encourage the practice of unsustainable industrial forestry in Canada. In this case, the calculated mid-range support payment for B.C. is $421-million, 1.8 percent of the value of shipments ($23.8-billion). In Alberta, this extrapolates to an estimated $75.6-million if the same percentage of subsidy and federal support is assumed, and $37.8-million if only half that percentage.

[x] For comparison, the Alberta Ministry of Environmental Protection expenditures were $489.8-million in 1998/99; direct forest management public expenditures in Alberta were $116.3-million in 1997.

In summary, the total public subsidy is an estimated $516.6-million if we assume the percentage of subsidies is the same in Alberta as in B.C., or $258.3-million if public subsidies and support are only half those in B.C.

Annual reports on the 1997 and 1998 economic impact of the forest industry in Alberta have been released by the Alberta Forest Products Association (AFPA), based on independent analysis by PriceWaterhouseCoopers. They report that AFPA member companies contributed $207-million in capital expenditures, $2.3-billion in operating expenditures (wages, salaries, raw materials, transportation, chemicals, energy supplies), $234-million in provincial tax revenue (direct and indirect income tax, corporate tax, stumpage and levies), $62-million in municipal taxes, and $278-million in federal tax payments in 1997.[92] Based on this report the total contribution to Alberta's economy is $2.803-billion; with the addition of the federal tax payments, the total is $3.081-billion. In comparison, the forest industry contribution to Alberta's GDP was a reported $2.372-billion in 1997.

If we subtract Alberta's estimated provincial support and subsidies, the provincial and municipal revenues decline to between $75.5-million and $145-million. Federal revenues of $278-million minus the estimated federal support and subsidies decline to between $202.4-million and $240.2-million in revenues.

Gale et al. (1999) also point out that the PriceWaterhouseCoopers report on the economic benefits of the B.C. forest industry does not take into account depletion of natural capital, thus dramatically overstating the net benefits of the sector. They use an interest/depletion approach, where the extent of natural capital depletion depends on the extraction ceiling selected.

Three extraction rate ceilings are presented in *Accounting for the Forests*.[93] The first is the minimum correction required, using an extraction rate ceiling equivalent to the Ministry of Forests' Long Term Harvest Level (LTHL). The LTHL for Timber Supply Areas in B.C. is 22 percent lower than the AAC. Gale et al.[94] note that at best only 78 percent of the proceeds from industrial forestry can be deemed income and that any timber extraction above this level involves depletion. This ceiling is based narrowly on the forest's ability to provide timber, and does not take into consideration ecological values.

A second correction advocated by Gale et al. (1999) is to estimate an extraction level consistent with ecosystem-based planning. They cite an estimated ecologically-sustainable extraction level based on plans for the Slocan Valley, undertaken by The Silva Forest Foundation (Hammond et al. 1996). The Slocan Ecosystem-Based Plan estimates a sustainable extraction rate less than 10 percent of the current AAC. Given the environmentally sensitive terrain in this region, this estimate cannot be applied across the province. Thus, Gale et al. (1999) estimate that the AAC needs to be reduced by about 70 percent to ensure that it would be sufficient to allow for implementation of ecosystem-based planning and the adoption of ecoforestry practices.

However, a more moderate estimate of natural capital depletion rate is given as a mid-range (46 percent), thus income is an estimated 54 percent. Using these estimates, the net contribution of the Forest Sector to Government Finances can be tabulated using the Gale et al. (1999) methodology and estimates (Table 8).

Table 8: Net Contribution of Alberta's Forest Sector to Government Finances when Natural Capital Depletion, Provincial Subsidies and Support, and Federal Subsidies and Support Are Taken into Account, 1997

Category of Revenue or Expense	Natural Capital depletion at 22% (based on MOF LTHL)	Natural Capital depletion rate at 46% (intermediate scenario)	Natural Capital depletion at 70% (based on ecosystem-based plans)
Gross industry contribution to federal revenue	278,000,000	278,000,000	278,000,000
Less allowance for natural capital depletion	- $61,160,000	- 127,880,000	- 194,600,000
Less federal subsidies	-$37,800,000 (low-end estimate) -$75,600,000 (higher-end estimate)	-$37,800,000 (low-end estimate) -$75,600,000 (higher-end estimate)	-$37,800,000 (low-end estimate) -$75,600,000 (higher-end estimate)
Net federal contribution	179,040,000 (low) 141,240,000	112,320,000 (low) 74,520,000	45,600,000 (low) 7,800,000
Gross industry contribution to provincial revenue	$234,000,000	$234,000,000	$234,000,000
Less allowance for natural capital depletion	-$51,480,000	-$107,640,000	-$163,800,000
Less provincial subsidies	-$220,500,000 (low-end estimate) -$441,000,000 (higher-end estimate)	-$220,500,000 (low-end estimate) -$441,000,000 (higher-end estimate)	-$220,500,000 (low-end estimate) -$441,000,000 (higher-end estimate)

10.2. Non-Timber Forest Values

Using the Green Area of Alberta and the estimated non-timber forest values identified by Haener and Adamovicz,[95] we extrapolated the values of non-timber forest values for the province's forested area. In Table 9, the total Alberta non-timber forest values are estimated at $25.31 per hectare per year.

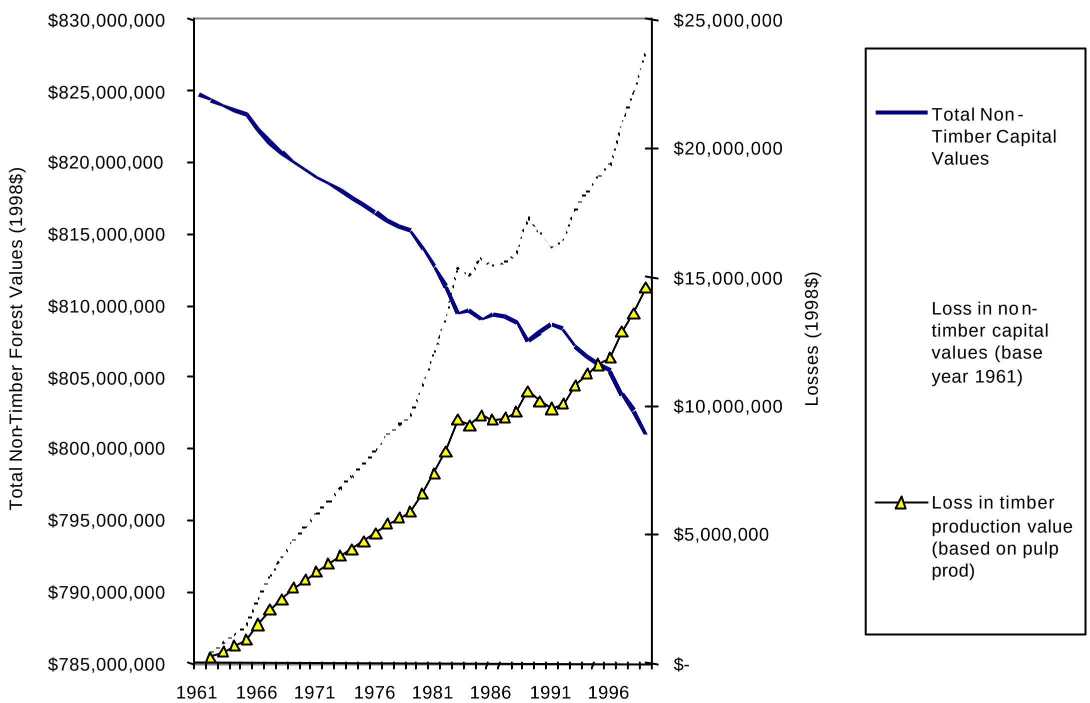
Table 9: Alberta's Non-Timber Forest Values

	1998$ per ha land area
Commercial Use	
Fishing	0.04
Trapping	0.06
Recreational Use	
Hunting	0.09
Fishing	0.23
Camping	0.03
Subsistence use	
Aboriginal land use	2.54
Biodiversity maintenance	8.41
Carbon sequestration	14.36
Total	25.31

Note: Carbon sequestration value is based on the Alberta GPI Carbon account

Using the per hectare values and the forest land area account, the change in non-timber values was estimated between 1961 and 1999. In 1961, the non-timber forest values were an estimated $824.8-million (1998$) and by 1999 these values had declined to $801.0-million (1998$). Figure 14 shows the change in non-timber values as well as the cumulative losses in non-timber and timber annual values. Based on the change in forest area since 1961, an estimated $23.8-million per year was lost in non-timber forest values, and $14.6-million in potential pulp production.

Figure 14: Total Non-Timber Values, Losses in Non-Timber Values, and Losses in Timber Production based on Pulp Production due to Losses in Forest Area, 1961 to 1999



The estimates used here are quite conservative in relation to other estimates of non-timber forest values. For example, Costanza et al. (1997)[96] estimated $384.52 per hectare per year (1998$Cdn). Using this estimate, the value of Alberta's non-timber forest values dropped from $12.3-billion in 1961 to $12.0-billion in 1999, a loss of $355.5-million per year as of 1999.

10.3. Total Economic Value of Timber Capital

Statistics Canada has developed Monetary Timber Asset Accounts (MTAA). The MTAA represent the annual estimates of the value of standing timber on Canada's timber-productive, stocked, accessible forest land base. Two methods can be used to calculate economic rent analysis. The first method uses a net present value (PV1) formula assuming positive returns to capital; the second method uses a net present value (PVII) formula assuming zero returns to capital. Method 2 yields higher values than method 1.

Table 10 shows that the value of Alberta's timber capital stock in 1997 (the most recent estimate) ranged from $12,945-million (PVI) to $16,913-million (PVII). The total Canadian timber capital stock is valued at between $233,452-million (PVI) and $268,259-million (PVII). These monetary value accounts are useful for expressing the current monetary values of the growing stock of timber capital inventory on the land, if the timber were allocated to commercial use. While interesting from the perspective of market values of timber capital, the monetary wealth accounts tell us little about physical sustainability and carrying capacity of the forest ecosystem as a whole.

Table 10: Alberta Timber Capital Monetary Value Account

Value of Alberta's Timber Capital Stocks		
	Value of Timber Stock (Method 1, PVI)	Value of Timber Stock (Method 2, PVII)
1961	14.3	92.7
1962	21.1	99.5
1963	86.2	163.7
1964	110.6	187.2
1965	116.8	192.8
1966	141.3	216.3
1967	167.6	241.4
1968	157.2	230.3
1969	162.7	235.4
1970	175.7	248.1
1971	204.8	277.0
1972	261.2	340.0
1973	363.0	462.1
1974	479.6	615.6
1975	533.8	716.4
1976	567.0	803.4
1977	577.6	869.3
1978	636.9	976.9
1979	670.0	1,055.0
1980	610.2	1,046.1
1981	497.3	986.9
1982	267.2	817.0
1983	91.8	703.2
1984	17.3	677.8
1985	-	685.3
1986	45.8	754.5
1987	528.3	1,262.1
1988	1,002.6	1,846.2
1989	858.5	1,979.4
1990	948.4	2,437.7
1991	591.7	2,477.6
1992	96.1	2,472.1
1993	-	2,844.1
1994	2,263.0	5,482.5
1995	7,024.2	10,569.1
1996	10,210.1	14,031.5
1997	12,945.1	16,913.1

Notes:

1. PVI (net present value I method) expresses values based on a present value calculation that assumes a positive return to capital (present value I).
2. PVII (net present value II method) expresses values based on a present value calculation that assumes a zero return to capital (present value II).

For a description of this method, see page 37 of the *Concepts, Sources and Methods of the Canadian System of Environmental Resource Accounts.*

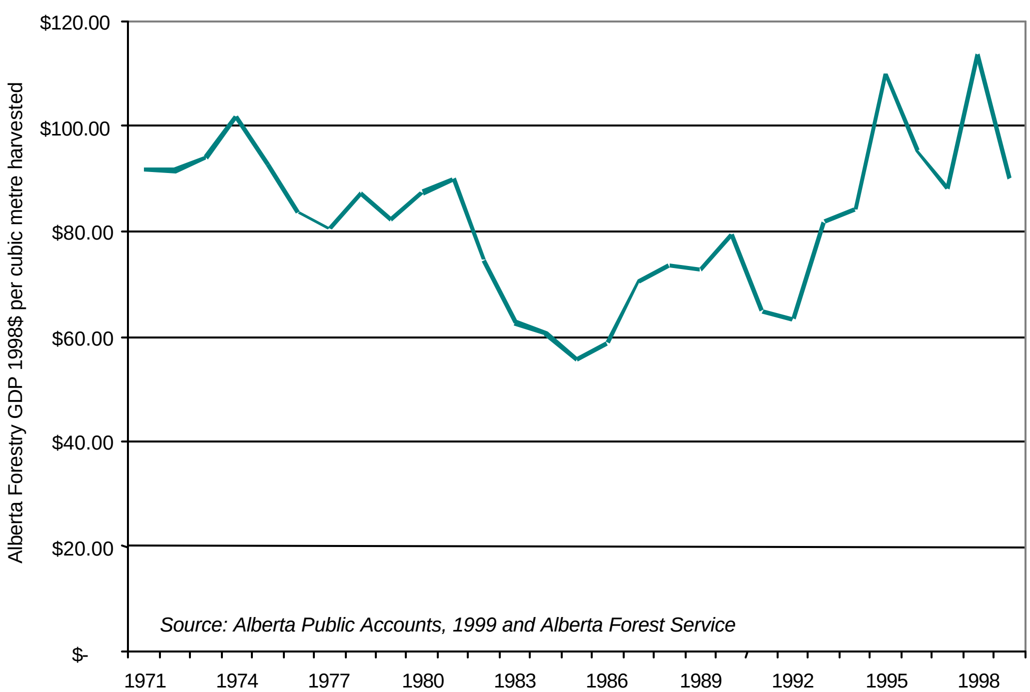
Catalogue No. 16-505-GPE, which is included in PDF format on the *Econnections, Indicators and Detailed Statistics 2000* CD-ROM.

10.4. Indicator 12: Forestry GDP per Cubic Metre Harvested

One measure of return on timber capital is the ratio of the GDP of Alberta's forest industries to annual timber harvest volumes (Figure 15). Using Alberta economic and national accounts, we derived a forestry GDP for Alberta from 1971 to 1999, combining the GDP values of forestry (logging); wood industries (lumber, panelboard and other); and pulp, paper and allied industries. In 1971, these three combined produced a forestry GDP of $87.0-million (current dollars) or 1.1 percent of Alberta's GDP. By 1999, Alberta's forestry GDP had risen to $2,179-million (current dollars) or 1.9 percent of Alberta's GDP.

Converting these forestry GDP figures to a value per cubic metre of wood harvested shows that despite massive investments in forest industry development over the past 30 years, the GDP per cubic metre of wood harvested actually fell throughout the 1970s and up to 1985. In 1971, forestry GDP per cubic metre harvested was $91.83 (1998$), falling to a low of $55.68 in 1985. The GDP returns increased from 1985, reaching a peak of $110.06/cubic metre in 1995.[y] Ironically, forestry GDP per cubic metre harvested was actually lower in 1999 at $90.05 than in 1971.

Figure 15: Alberta Forestry GDP per Cubic Metre of Wood Harvested, 1998$



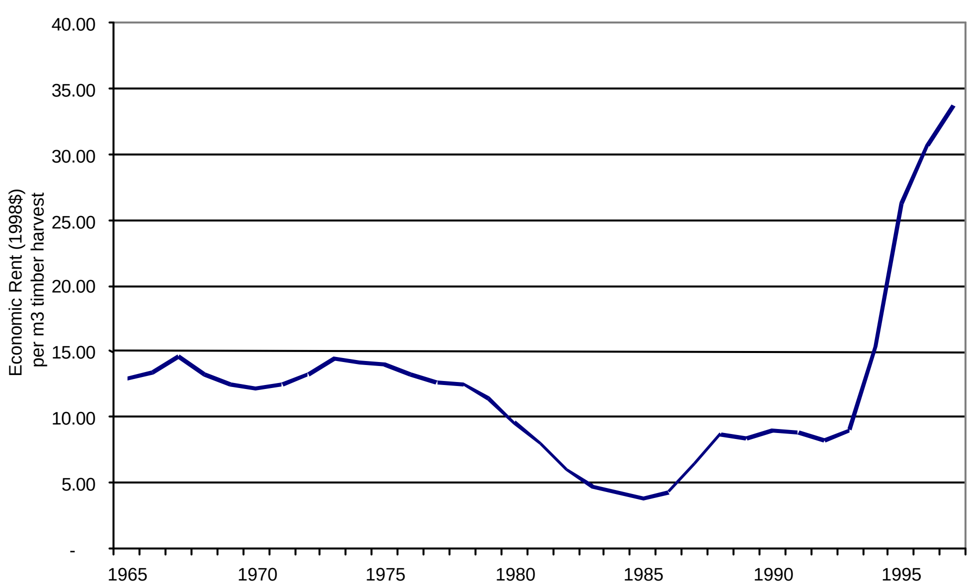
[y] 1998 recorded a higher GDP per cubic metre harvested, at $113.71; however, this is artificial since LFS harvest statistics in 1998 exclude fire salvage volumes.

10.5. Indicator 13: Rate of Economic Return per Cubic Metre Harvested

Another measure of the economic return per unit of timber harvested is the economic rent. Economic rent is the return to the owner of the resource—Albertans—from each cubic metre of timber harvested over and above payments to industry, which harvests the timber. Not all of these rents accrue to Albertans in the form of stumpage fees and taxes; a portion accrues to the federal government in the form of corporate income taxes, an aspect that was analyzed by Anielski in 1991.[97] The rent collected by the Alberta government has been affected by recent changes to Alberta's stumpage system for both saw logs and pulp, a shift to a market-based rate that is more sensitive to market prices, production costs, and returns to capital. These changes have resulted in higher returns (i.e., a larger share of economic rent) to the Crown than in the past.

Using Statistics Canada's Monetary Timber Asset Accounts, we derived an average annual economic rent per cubic metre of wood harvested (using method 2, PVII). Figure 16 shows the trends in real (1998$) rate of economic return per cubic metre of timber harvested. According to the Statistics Canada monetary accounts for Alberta timber capital, the rents per cubic metre harvested remained relatively constant throughout the 1960s, 1970s and 1980s then rose in the 1990s. Average resource rents rose 260 percent, from $12.88/cubic metre in 1965 to $33.73/cubic metre of wood harvested in 1997. This dramatic increase cannot be fully explained or reconciled with the forestry GDP per cubic metre harvest figures, which showed stagnant returns per unit harvested. The increasing rents may be attributed to rising forest product prices relative to flat or declining production costs.[98] A more detailed analysis of Statistics Canada's data, including production costs and capital costs, is recommended for future analysis.

Figure 16: Economic Return per Cubic Metre of Wood Harvested



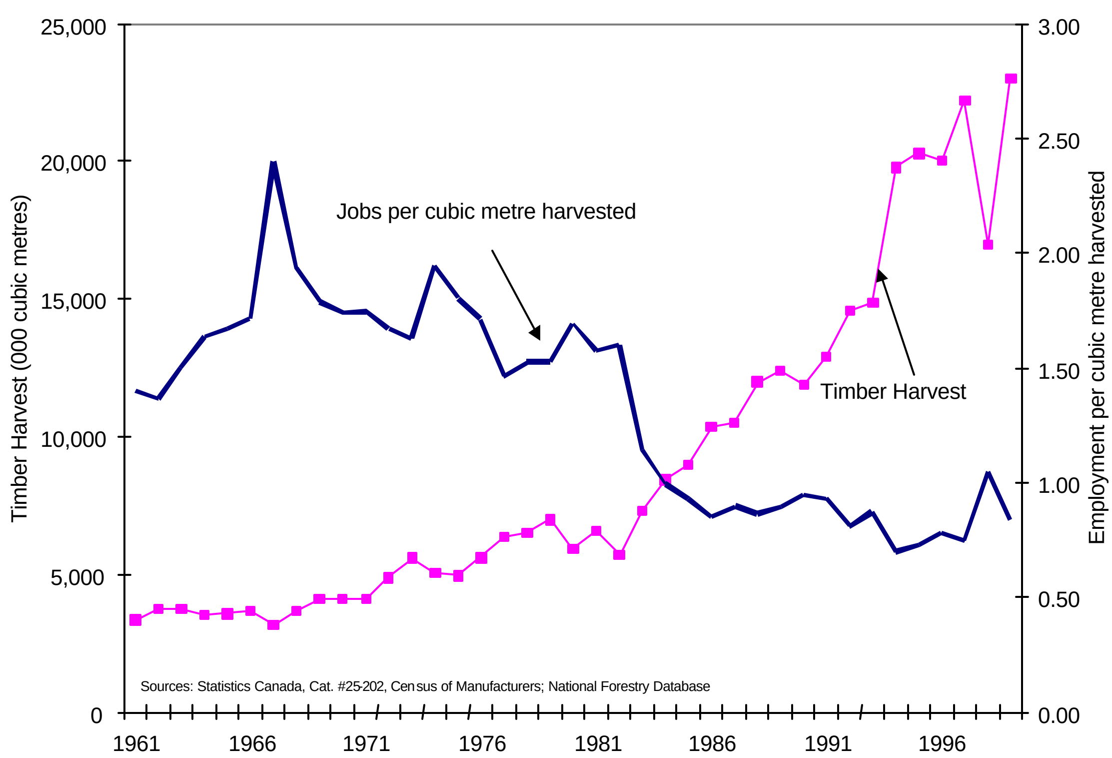
Source: Statistics Canada, *Econnections*, special monetary accounts table for Alberta timber capital, using PVII method

10.6. Indicator 14: Forestry Jobs

We can also express returns to timber capital in terms of forestry employment, or jobs per tree harvested. Forestry employment (logging, wood industries, pulp and allied)[99] has risen steadily since 1961 from a labour force of 4,701 to an estimated 19,209 in 1999.

However, Figure 17 tells a different story, showing employment per cubic metre of timber harvested falling over the past 40 years while timber harvesting has increased. The volume of trees harvested has increased 563 percent since 1961, while the number of jobs per volume of trees harvested fell 46.8 percent over the same period. Employment per thousand cubic metres of wood harvested was 1.40 jobs in 1961, peaking at 2.40 jobs in 1967, then dropping to its lowest point in 1995 at 0.73 jobs. In 1999, we estimate that employment per 1000 cubic metres harvested was 0.835 lower than in 1961, 1971, or 1981. This is the result of increased capital investments and efficiency improvements. While efficiency gains should be celebrated, they have come at a cost to human and social capital by reducing employment in the forest.

Figure 17: Forestry Employment per Thousand Cubic Metres of Timber Harvested versus Harvest Volume



11. Conclusions

The GPI forestry accounts report for Alberta attempts to address the fundamental question: Are Alberta's forests sustainable now and for the benefit of future generations—sustainable, not only in terms of the natural capital flows of timber but also in terms of the integrity of complex, living systems called forests? To answer these questions, the Alberta GPI forestry capital accounts were developed along the lines of a traditional balance sheet, income statement and ledgers to assess the genuine wealth, or condition of the well-being, of Alberta's forests. The forest accounts take a "capital" approach to assessing the sustainability of forests as renewable natural capital, including the physical stock of forest capital and the flow of timber volume and ecosystem services from 1961 to 1999.

The forest accounts also examine the market returns on forest capital in terms of forest economic rents generated as a result of converting timber capital into forest products for domestic consumption and export. The monetary forest accounts thus answer the question of whether Albertans are receiving a reasonable return on each tree harvested, in terms of stumpage and tax revenues and in terms of jobs. The forest accounts also examine other important trends in forest ecosystem services, particularly their role in carbon sequestration.

From the Alberta GPI forest accounts a number of indicators of forest ecosystem sustainability can be derived. We examined 14 key indicators of forest sustainability, which revealed the following trends between 1961 and 1999:

1. **Timber Sustainability Index** declined 75.5 percent.
2. **Productive forest land area** declined 2.9 percent to 17.825 million hectares in 1999.
3. **Forest age-class distribution** saw a significant loss of old age classes with an estimated 42 years before all old age classes are harvested, burned or removed for oil, gas and agricultural development.
4. **Harvesting rates** increased 586.1 percent by volume for an accumulated total of 351.9 million cubic metres from 1961 to 1999.
5. **Forest fragmentation and cumulative impacts of forest land development:** Fragmentation increased from a mere 3.5 percent of Alberta's forests in 1961 to 90.7 percent by 1999.
6. **Insect and disease infestation:** Between 1975 and 1999 an accumulated estimate of 23.68 million hectares of productive forest were infested with insects and/or disease.
7. **Fire:** An accumulated total of 5.06 million hectares or 167.8 million cubic metres of fibre burned (47.7 percent of timber volume harvested) on Crown forest land between 1961 and 1999.
8. **Biodiversity and forest species health:** Both grizzly bear and woodland caribou populations and their effective habitat declined.
9. **Reforestation:** Thirty-three percent of the Crown forest land harvested since 1975 is considered as a "reforestation liability"; that is, it remains "understocked".
10. **Watershed development"** Over 50 percent of Alberta's watersheds are "developed" in terms of industrial activity and land use development, according to the World Resources Institute.
11. **Carbon sequestration:** Alberta's forests and peatlands have the capacity to sequester no more than 25 percent of total carbon emissions from anthropogenic sources.
12. **Real forestry GDP** per cubic metre harvest: Total real (adjusted for inflation) forestry GDP increased 330.1 percent from 1971 to 1999, however, real forestry GDP per cubic metre of timber harvested actually declined by 1.94 percent from 1971 to 1999, to $90.05 (1998$) per cubic metre.

13. **Economic return (rent) per cubic metre of timber harvested** increased 162 percent from 1961 to 1997 to an estimated $33.73 (1998$) per cubic metre harvested.
14. **Forestry employment per cubic metre of timber harvest** declined 40.4 percent from 1.4 jobs per 1000 cubic metres harvested in 1961 to 0.83 jobs per 1,000 cubic metres harvested in 1999.

Assessing the health, integrity and sustainability of complex living systems such as forests is no easy accounting task. Yet, the GPI forest accounts and the 14 forest sustainability indicators suggest that while the economic benefits in terms of Alberta's forestry GDP have increased handsomely in 40 years there are reasons to be concerned about the long-term sustainability of Alberta's timber supply and the condition of the forest ecosystem at current rates of industrial development and human impacts. While threats for forest sustainability may not be immediately apparent, the ongoing risk of fire and the cumulative impact of oil, gas and other forest land development throughout the province do point to the potential for risk to the long-term economic viability (i.e., sustained timber supplies) of some forestry operations.

If sustainability of forests is defined by living off the interest of forest capital then, at a minimum, sustainability of timber supplies requires a rate of harvesting plus other depletions that does not exceed the annual rate of growth of the timber capital stock. From the GPI forest accounts it would seem that that the timber sustainability threshold was exceeded for two consecutive years—in 1998 and 1999. Even conventional ratios of harvest volumes to the annual allowable cut suggest a need for prudence and frugality in managing Alberta's timber capital stocks.

Forests are more than simply timber fibre supply factories. They are living, dynamic systems made up of complex interactions and interrelationships of flora and fauna whose integrity must be accounted for within an accounting framework that mimics the forest as a living system. The GPI forest accounts are far from living system accounts that reflect the complex interrelationships that ultimately define the integrity of forests. However, the GPI forestry accounts developed for Alberta, consistent with the structure of Statistics Canada's environment and natural resource accounts, hold considerable promise for accounting for the human pressures and demands on forest capital and forest ecosystem services that will eventually lead us to a greater understanding of how to account for forest ecosystem health.

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Appendix A. List of Alberta GPI Background Reports

A series of Alberta GPI background reports accompanies the *Alberta Sustainability Trends 2000* report and this report. These documents are being released in late 2001 and early 2002 and will be available on the Pembina Institute's website at www.pembina.org.

Alberta GPI Background Reports and Sustainability Indicators

GPI Background Reports	**GPI Accounts Covered by Report**
1. Economy, GDP, and Trade	• Economic growth (GDP) • Economic diversity • Trade
2. Personal Consumption Expenditures, Disposable Income and Savings	• Disposable income • Personal expenditures • Taxes • Savings rate
3. Money, Debt, Assets and Net Worth	• Household debt
4. Income Inequality, Poverty and Living Wages	• Income distribution • Poverty
5. Household and Public Infrastructure	• Public infrastructure • Household infrastructure
6. Employment	• Weekly wage rate • Unemployment • Underemployment
7. Transportation	• Transportation expenditures
8. Time Use	• Paid work time • Household work • Parenting and eldercare • Free time • Volunteerism • Commuting time
9. Human Health and Wellness	• Life expectancy • Premature mortality • Infant mortality • Obesity
10. Suicide	• Suicide
11. Substance Abuse; Alcohol, Drugs and Tobacco	• Drug use (youth)
12. Auto Crashes and Injuries	• Auto crashes
13. Family Breakdown	• Divorce
14. Crime	• Crime
15. Gambling	• Problem gambling
16. Democracy	• Voter participation
17. Intellectual Capital and Educational Attainment	• Educational attainment
18. Energy (Oil, Gas, Coal and Renewable)	• Oil and gas reserve life • Oilsands reserve life
19. Agriculture	• Agricultural sustainability
20. Forests	• Timber sustainability • Forest fragmentation
21. Parks and Wilderness	• Parks and wilderness

GPI Background Reports	**GPI Accounts Covered by Report**
22. Fish and Wildlife	• Fish and wildlife
23. Wetlands and Peatlands	• Wetlands • Peatlands
24. Water Resource and Quality	• Water quality
25. Energy Use Intensity, Greenhouse Gas Emissions and Air Quality	• Energy use intensity • Air quality-related emissions • Greenhouse gas emissions
26. Carbon Budget	• Carbon budget deficit
27. Municipal and Hazardous Waste	• Hazardous waste • Landfill waste
28. Ecological Footprint	• Ecological footprint

Appendix B. Forestry GPI Data and Environmental Costs

	Timber Sustainability Index, the ratio of annual increment (growth) divided by total harvest, energy and agriculture depletions	Timber Sustainability Index for GPI Wheel uses a benchmark of a TSI=1.10 providing 10% addition room for risk, a TSI over 1.10 gets a 100 point score.	Percentage of Alberta's forests (Boreal and Foothill) that remain unfragmented, based on WRI report	Fragmentation Index where 100 represents no fragmentation
1961	3.90	100.00	96.7%	96.66
1962	4.07	100.00	95.8%	95.75
1963	4.10	100.00	94.8%	94.85
1964	4.72	100.00	93.9%	93.94
1965	4.68	100.00	93.3%	93.26
1966	3.85	100.00	91.5%	91.52
1967	4.32	100.00	90.0%	90.02
1968	3.27	100.00	88.7%	88.74
1969	3.73	100.00	87.4%	87.36
1970	3.72	100.00	86.1%	86.15
1971	4.23	100.00	85.0%	84.96
1972	3.13	100.00	83.7%	83.67
1973	3.90	100.00	82.4%	82.38
1974	3.67	100.00	81.2%	81.20
1975	4.31	100.00	80.0%	79.96
1976	3.56	100.00	78.6%	78.65
1977	3.61	100.00	77.2%	77.19
1978	3.70	100.00	75.9%	75.87
1979	2.54	100.00	74.3%	74.26
1980	1.30	100.00	71.5%	71.50
1981	0.98	86.92	68.5%	68.54
1982	1.04	92.30	65.2%	65.18
1983	2.43	100.00	60.8%	60.76
1984	2.28	100.00	56.8%	56.84
1985	2.30	100.00	53.0%	52.99
1986	2.05	100.00	49.0%	48.96
1987	1.63	100.00	43.5%	43.45
1988	1.91	100.00	39.8%	39.81
1989	1.98	100.00	36.9%	36.94
1990	2.31	100.00	36.2%	36.24
1991	2.36	100.00	34.7%	34.65
1992	2.05	100.00	32.2%	32.19
1993	1.66	100.00	28.0%	27.99
1994	1.44	100.00	24.6%	24.57
1995	0.77	70.34	22.2%	22.20
1996	1.53	93.46	20.4%	20.38
1997	1.24	93.34	17.0%	17.00
1998	0.51	33.18	14.0%	14.03
1999	0.96	78.90	10.9%	10.95

	Cost of non-timber forest values due to change in productive forest (millions, 1998$)	Cost of Unsustainable Timber Resource Use (loss in pulp production value) (millions, 1998$)
1961	-	-
1962	0.39	0.24
1963	0.78	0.48
1964	1.11	0.68
1965	1.47	0.90
1966	2.49	1.53
1967	3.38	2.08
1968	4.11	2.52
1969	4.77	2.93
1970	5.30	3.25
1971	5.82	3.57
1972	6.31	3.87
1973	6.81	4.18
1974	7.28	4.47
1975	7.75	4.75
1976	8.26	5.07
1977	8.84	5.43
1978	9.24	5.67
1979	9.60	5.89
1980	10.78	6.61
1981	12.07	7.41
1982	13.46	8.26
1983	15.37	9.43
1984	15.08	9.25
1985	15.75	9.67
1986	15.42	9.46
1987	15.56	9.55
1988	15.93	9.78
1989	17.25	10.58
1990	16.65	10.22
1991	16.15	9.91
1992	16.42	10.08
1993	17.62	10.81
1994	18.33	11.25
1995	18.92	11.61
1996	19.35	11.87
1997	21.02	12.90
1998	22.16	13.60
1999	23.78	14.60

Appendix C. CCFM, World Bank and OECD Forestry Indicators

CCFM Criteria and Indicators for Sustainable Forest Management

(a selection of those indicators proposed, which could be shown using this account)

Biological Diversity

1.1.1 Percentage and extent, in area, of forest types relative to historical conditions and to total forest area
1.1.2 Percentage and extent of area by forest type and age class
1.1.4 Level of fragmentation and connectedness of forest ecosystem components

Forest Ecosystem Health, Condition and Productivity

2.1.1 Area and severity of insect and disease attack and infestation
2.1.3 Area and severity of fire damage
2.2.1 Percentage and extent of area by forest type and age class
2.2.2 Percentage of area successfully naturally regenerated and artificially regenerated
2.3.1 Mean annual increment by forest type and age class

Conservation of Soil and Water Resources

3.1.2 Area of forest converted to non-forest land use
3.2.1 Percentage of forest managed primarily for soil and water protection

Forest Ecosystem Contributions to Global Ecological Cycles

4.1.1 Tree biomass volumes
4.1.5 Soil carbon pools
4.1.6 Soil carbon pool decay rates
4.1.7 Area of forest depletion
4.1.8 Forest wood product life
4.1.9 Forest sector CO_2 emissions
4.2.1 Area of forest permanently converted to non-forest land use
4.2.2 Semi-permanent or temporary loss or gain of forest ecosystems
4.3.1 Fossil fuel emissions
4.3.2 Fossil carbon products emissions
4.5.1 Surface area of water within forested areas.

Multiple Benefits to Society

Productive Capacity

5.1.1 Annual removal of forest products relative to the volume of removals determined to be sustainable.
5.1.2 Distribution of, and changes in, the land base available for timber production
5.1.4 Management and development expenditures
5.2.1 Net profitability (economic rents)
5.2.2 Trends in global market share.
5.3.1 Contribution to GDP of timber and non-timber sectors of the economy
5.3.2 Total employment in all forest-related sectors
5.3.3 Utilization of forests for non-market goods and services, including forest land use for subsistence purposes
5.3.4 Economic value of non-market goods and services
5.4.2 Total expenditures by individuals on activities related to non-timber use
5.4.4 Area and percentage of protected forest by degree of protection

OCED Environmental Indicators for Forest Resources

The Organisation for Economic Co-operation and Development (OECD) has proposed the following set of short- and long-term environmental indicators for forest resources:

- Productive capacity = rate of harvest versus productive capacity of the forest
- Area and volume distribution of forests
- Share of disturbed/deteriorated forests in total forest area
- Percentage of harvest area successfully regenerated (including natural regeneration)
- Percentage of protected forest in total forest area

World Bank Ideas for Forest Sustainability Indicators

The World Bank suggests several approaches for examining the composition, condition, continuity, and management of forests. These include:

Forest area and supply

- Standing tree volumes
- Percentage change in forest cover types
- Total biomass
- Harvest of old growth forest vs. new growth
- Harvest vs. mean annual increment (OECD)
- Comparing projected supply and demand patterns with MAI.
- Productive yield relative to managed stands
- Comparison of natural and managed landscapes
- Representation of forest ecosystems in viable protected areas
- Areas planted with indigenous species

Forest health and integrity (impact of natural and human disturbance on viability and productivity of forest ecosystems).

- Forest condition (to determine whether secondary forests are degraded to sustain species adapted to primary forest habitat). An indicator would be the population of top predators in the ecosystems or populations of species or groups of species that influence ecosystem processes.
- Level of disturbance of remaining natural forests
- Agricultural and other land use disturbance patterns
- Continuity of available (non-reserved) wood supply (productive forest land base)
- Carbon budgets
- Watershed indicators—soil erosion, soil stabilization, turbidity and siltation of waterways
- Soil nutrient status

Fragmentation (habitat continuity)

- Fragmentation of the forests, including impacts of human and natural disturbance on watersheds, forest ecosystems, wildlife habitat (to decide whether the remaining continuous areas of forest are sufficient for species survival)
- Population trends in migratory species and representative fauna
- Area of forest types which support given species of wildlife

Appendix D. U.S. GPI Methodology for Loss of Forests

The U.S. GPI estimates include an estimate of the cost of the loss of old growth forest. These and other detailed GPI methodological descriptions for the U.S. GPI analysis can be found in Anielski and Rowe (1999);[100] readers are referred to the work by Anielski and Rowe for details on references cited in this appendix.

Cost of Loss of Forests

Whenever forest land is cut for timber or to build a road, a range of ecological values is lost, at least until the forest is regenerated to the same age as the stand that has been cut. Even if successful forest management results in full restocking of the same species of timber, the original forest ecosystem may never be renewed. Forest management that focuses primarily on the timber capital may preclude the species complexity and thus the ecosystem services of the original forest. If the forest is cut or regenerated improperly, or if the size of the total cut is sufficient to drive unique species into extinction, the damage from roadbuilding, cutting, and reforestation can be effectively permanent.

In theory, an account of value of forest ecosystems should account for the loss of forest ecosystem integrity and ecological services and the cost of unsustainable forest management practices. Conceptually, we focus on two distinct, though interrelated, types of costs associated with roadbuilding and timber harvesting. One is resource loss: the reduction in the amount of timber that can be harvested in the future. The other is ecological: the destruction in species of both plants and animals. Our analysis, however, only focuses on the old growth forest of the Pacific Northwest thus precluding analysis of the loss of ecological services that may have been realized on vast areas of other U.S. forest lands, most of which are now managed and thus no longer in their original or old growth state. We believe our estimates of the loss of forests are conservative. Future accounts should account for the value of sustainable or unsustainable timber capital, which is under managed conditions, as well as the economic losses of ecological services due to loss of forest ecosystem integrity and biodiversity.

Replacing complex, old-growth forests with monoculture tree farms creates the impression that the first cost can be easily managed. In fact, the net growing stock of softwoods in the United States has remained approximately constant since the 1950s, and the stock of hardwoods has increased (Powell 1988, p. 50). (Softwood volume grew from 432 billion cubic feet in 1952 to 467 billion in 1977, then fell to 450 billion in 1992. The net stock of hardwood has increased significantly from 1952 to 1992: from 185 billion to 336 billion cubic feet.)

Yet the forests or tree farms that have replaced old-growth forests are not biologically equivalent. Tree farms are productive and profitable, at least for one or two rotations of the timber stock; but they do not support the range of wildlife that can be found in old-growth forests. In addition, commercial silviculture makes demands on soil that are not sustainable. In the Pacific Northwest, 80-year-rotation tree harvesting removes around 1,000 pounds of nitrogen per acre from the soil, whereas old-growth forests tend to add 2,000 to 4,000 pounds of nitrogen per acre (Norse 1988). Thus, even when the accounts show an increase in total volume of wood, the living resource is likely to have been diminished.

Our estimate of non-market or environmental values is based largely on the changing stock of old-growth forest. Much of the debate over the amount of remaining old-growth forest hinges on definition. Old-growth forest in the Pacific Northwest has been defined by the U.S. Forest Service since 1986 as stands with at least eight trees per acre over 200 years old or 32 inches in diameter, a specific density of conifer snags, and two or more tree species (Old-Growth Definition Task Group 1986, and Peter Morrison 1988). Some studies have used less restrictive definitions based entirely on the age of stands.

However, even the most restrictive definitions may understate the ecological losses from edge effects: ten isolated 100-acre stands have far less ecological value than a single 1,000-acre stand. As a result of such factors, any numerical estimate of loss will be imprecise.

The discrepancy in the definition of old-growth forest is epitomized by the following two examples. The U.S. Forest Service estimates that of an estimated 16.4 million acres in their Pacific Northwest (PNW) plan area, 52 percent is estimated to be currently in a large-tree or old-growth condition. Their plan projects an increase to 73 percent over the long-term. They also note that "the PNW plan anticipates that forests of young trees will continuously occupy about 20 to 40 percent of these lands. In areas of scheduled timber management, the plan would maintain about 50 percent of the forest in a large-tree or old-growth condition."

A second study by Bolsinger and Waddell (1993) estimated that old-growth forests in California, Oregon, and Washington cover about 10.3 million acres. Estimates were obtained for National Forests, national parks, state parks, state forests, Bureau of Land Management land, U.S. Fish and Wildlife Service land, Native American land, and private ownership. Oregon has almost half of the old-growth acres with about five million acres in seven different ownerships. More than 80 percent of the old growth is on federal land, primarily National Forests. Old growth occupied about half of the forest area when the first comprehensive forest surveys were done in the 1930s and 1940s. They conclude that less than 20 percent of the original forest area is now old growth.

To estimate the cost of losing old-growth forests, we assume that the forgone benefits are directly related to the cumulative erosion of the ecosystems composed of these forests. Although a few secondary forests in the Northeast, Midwest, or Southeast may have been re-growing long enough to qualify as old growth, we have assumed that the remaining old growth of consequence is limited to the Pacific Northwest. Furthermore, since most of the old-growth forest on private lands appears to have been cut by 1950, we focus exclusively on that remaining in National Forests.

From 1950 to 1997, we used rates of reduction of old-growth forests in the Pacific Northwest to estimate the additional cumulative cost of forest decline. This is based on the premise that the value of a diminishing resource for which there is increasing demand (in this case ecological amenities) increases at a growing rate as the supply declines. Each year, we added the loss of value to the cumulative loss up to that point because the erosion of ecological services from cutting an old-growth forest does not occur in the initial year alone but over a period of decades.

The rate of decline in old-growth forest from 1991 to 1997 from the 2.0 million acres assumed stock in 1990 is based on the growth rate of total roads in National Forests at 0.878 percent per annum. This is a purely arbitrary projection given that no official U.S. Forest Service statistics exist for old-growth forests. The rate of depletion, while undoubtedly slowing, may indeed be higher than our extrapolations suggest. This extrapolation assumes that road construction is uniformly distributed across all National Forests including old-growth forests. A more accurate picture would require road miles estimates for the Pacific Northwest region, which contains the majority of old-growth forest.

The initial estimated cost of the ecological services lost due to accumulated loss of old-growth forest in 1950 is estimated at $42.6-billion (1992 dollars). We assumed that the ecological value of the remaining old growth in National Forests in 1950 (beyond their value for timber or pulp) was $1,419 per acre ($1000/acre in 1982$ in the 1995 GPI). We assume that their value increased by five percent per year until only five million acres remained in 1967; by eight percent per year from 1968 to 1979; and by 10 percent per year from 1980 until the present. This reflects the increasing marginal value of old-growth forest as it declines. By 1994, an acre of old-growth forest is valued at $28,000 per acre (in 1992 dollars)—not as timber, but as a source of ecological and recreational values. By 1997, the estimated cost of old-growth forest loss is estimated at $78.2-billion, in 1992 dollars.

In addition to the loss of old-growth forests, the existence of roads in National Forests reduces the population of sensitive species that are affected by noise and traffic, erosion and sedimentation, and the increased presence of humans. These costs are especially pronounced during the construction period, but they persist through the life of the road to a lesser degree.

It might be argued that roads have non-market *benefits* because they increase access to forests. The evidence for this is the rise in visitor-days at various federal and state recreation areas, including National Forests. However, there is a certain irony in defining forest roads as a benefit in this respect. The elimination of most forests in the vicinity of urban areas over the past two centuries now forces urban dwellers to drive considerable distances to experience what at one time could have been enjoyed nearby. In some sense, recreational visits to the islands of "nature" in the midst of human artifacts have become another form of defensive expenditure to counteract the negative effects of urbanization. Thus, we have not treated those visits as a benefit.

The calculation of losses due to roads in the National Forests is based on the total stock of roads in any given year. A mile of forest road with a 60-foot right-of-way covers approximately seven acres of land. If the impacts such as noise, edge effects, and runoff are included, a mile of road affects at least 500 acres of land. This provides a very rough estimate of the environmental costs because the damage caused by roads depends on many factors including age, location, and slope, the quality of construction and the frequency of maintenance. Nevertheless, even the best roads cause some continuing ecological disruption by breaking up the landscape, raising erosion levels, disturbing downstream fisheries, and generally increasing the level of human activity.

Estimates of total miles of forest roads are taken from the 1950, 1955, 1960, 1965, 1970, 1975, 1981, and 1992 *Report of the Forest Service.* Although data were available for other years, they vary considerably, which suggests changes in sampling methods used. The method used here is to assume smooth growth between the Forest Service data points. For the period 1994 to 1997 statistics for the miles of roads in existence are from the *Report of the Forest Service* 1995, 1996, and 1997.

We assume that the cost of damages to the forest from roads from 1950 to 1959 is $14,194 per mile (1992 dollars), based on the 1995 GPI estimates of $10,000 per mile in 1982 dollars. From 1960 to 1979, the cost per mile is assumed to decline on a straight-line basis from $14,194 to $10,645 and to remain at $10,645 after that, in 1992 dollars. We estimate the cost of ecological damage due to roads at $4-billion in 1997.

The GPI estimates for the loss of old-growth forest due to resource loss and ecological service losses is $82.2-billion in the year 1997, in 1992 dollars.

Appendix E. Australian GPI Methodology for Loss of Native Forests

The Australian GPI for 2000 by Hamilton and Denniss estimated the cost of loss of native forests, which they deduct against GDP to derive the GPI estimates. The following text outlines their methodology taken directly from Hamilton and Denniss (2000).[101] Readers are referred to the work by Hamilton and Denniss for details on references cited in this appendix.

Costs of loss of native forests

When forests are cut the value of the timber products made from the logs is added to GDP. But the environmental costs associated with logging are not recorded anywhere. These costs include loss of biological diversity, falls in aesthetic and recreational values and diminution of non-use values, which are characterised by environmental economists as existence, bequest and option values.[z] To the extent that old-growth forests are able to return to their original state, the process may take 200 years or more. In Australia, the length and bitterness of the dispute over logging of old-growth forests (where conservation values are particularly high) suggest that Australians place a high value on these losses.

How should these losses be valued for the purposes of the GPI? We take the view that it is inappropriate to place economic values on loss of biodiversity and the losses experienced by people when they see an old-growth forest destroyed. These are ethical issues rather than economic ones (Hamilton 1994). However, since loss of old-growth forests may represent a large impact on well-being, we have decided to include a monetary estimate of the losses for comparison with the GDP measures of changes in welfare. Rather than attempting to value each component of loss, a comprehensive approach to monetary valuation can be obtained by estimates of willingness to pay for preservation of environmental values. (This approach is based on an anthropocentric ethic, one that many would regard as inappropriate.)

In 1991, the Resource Assessment Commission carried out a study of the environmental values of National Estate forests in Southeast NSW and East Gippsland. These forests cover an area of 130 000 hectares and had been declared by the Australian Heritage Commission to be of high conservation value. A contingent valuation survey revealed that adult residents of NSW and Victoria were willing to pay $22 per annum to preserve these forests (RAC 1992: U15).[aa] This translates into a total valuation for these forests of $156 million, or $1700/ha/annum, by the residents of the states in which the forests are located. Loss of old-growth forests is also felt by residents in other states, as campaigns over logging in Tasmania and the Queensland wet tropics illustrate. We might then scale up this amount by, say, 100 percent. On the other hand, these National Estate forests are of particularly high value, so a conservative approach may be to halve this estimate of the environmental values of a hectare of old growth. Thus we estimate that the logging of each hectare of old-growth forest results in a loss of environmental values of $1700 per annum. Since the losses are effectively irreversible, the value of each hectare lost needs to be capitalised. At a 5% discount rate, the present value of the environmental losses from each hectare logged is $34 000.

[z] In addition, where it occurs, overcutting diminishes the productivity of the forests and reduces the future timber values of the forest. The ability of the forests to renew their timber values is damaged. This factor is not included in the analysis.

[aa] This figure is a median willingness to pay rather than a mean. The mean is not reported.

Remarkably, data on areas of old-growth forest logged over the study period, or indeed for any year, are not available. We have therefore been forced to make some rough estimates. The area of native forest available for logging in 1990 was around 22 million hectares (ABS 1995: Table 4.3). However, not all of this area is suitable for logging, so we estimate that only 15 million hectares are available in practice. If these forests are managed on a 100-year rotation,[bb] this means that 150 000 hectares are logged each year. We assume that when logging of native forests reached its peak in the late 1980s this was the area logged. For other years we are forced to make a rough estimate using data on timber volumes extracted from native forests as reported in DEST (1996b: 6-41). The estimated cost of environmental damage due to logging of old-growth forests for the year 2000 is $5.7 billion (in 1989-90 prices). As a result of the uncertainties in estimating both the areas logged and the environmental values lost due to logging, the estimates of the costs of logging native forests should be viewed as only very rough approximations.

[bb] See Streeting and Hamilton (1991).

Endnotes

[1] See other sections of this report for sources of information, including sections 10.1 to 10.6.
[2] Alberta Environmental Protection.1996. *The Status of Alberta's Timber Supply,*" May 1996; p. 4
[3] See http://www.gov.ab.ca/env/forests/fmd/legacy/legacy.html for Alberta Forest Legacy document.
[4] http://www.borealcentre.ca/reports/sfm.html#DEFINITION
[5] Wilson, Sara. 1999. *The GPI Forest Accounts: Ecological, Economic and Social Values of Forests in Nova Scotia*. GPI Atlantic, Halifax.
[6] See http://www.pfc.forestry.ca/monitoring/inventory/canfi/pubs_e.html for access to Canada's National Forest Inventory.
[7] Anielski, Mark. 1992. *Resource Accounting: Indicators of the Sustainability of Alberta's Forest Resources.* Paper presented at the International Society of Ecological Economics meeting in Stockholm, Sweden, August 1992.
[8] Anielski, Mark. 1996. "Accounting for the Sustainability of Alberta's Forests - The 1995 Timber Resource Account." Unpublished paper. Edmonton, Alberta. Republished in Anielski, Mark.1997. "Is Alberta Running Out of Nature's Capital (Alberta's oil, gas, and coal natural capital accounts)." Presentation to the Department of Economics, University of Alberta, March 1997.
[9] See Statistics Canada. 1996. *Econnections: Concepts, Sources and Methods*. Natural Resource Stock Accounts. Cat. no. 16-505-GPE
[10] Kirshnaswamy, A, and Hanson, A. 1999. *Our Forests Our Future: A summary report on the World Commission on Forests and Sustainable Developmen*t. World Commission on Forests and Sustainable Development, Canada.
[11] See World Resources Institute. 2000. *Canada's Forests at a Crossroads: An Assessment in the Year 2000*. A Global Forest Watch Canada Report, Washington, D.C. for a detailed description of each indicator category.
[12] Statistics Canada. 1997. *Econnections: Linking the Environment and the Economy*. Cat. No. 16-505-GPE, December 1997, Ottawa
[13] Statistics Canada. 2001. *Econnections: Linking the Environment and the Economy*: Indicators and Detailed Statistics. Cat. No. 16-200-XKE, February 2001, Ottawa http://www.statcan.ca/english/IPS/Data/16-200-XKE.htm
[14] See Lowe, J.J.; K. Power, S.L. Gray. 1994. *Canada's forest inventory 1991*. Natural Resources Canada, Canadian Forest Service, Petawawa National Forestry Institute, Information Report PI-X-115. See also, J.J. Lowe, K. Power, S.L. Gray. *Canada's forest inventory 1991: The 1994 version*. Natural Resources Canada, Canadian Forest Service, Victoria, Information Report BC-X-362E; and J.J. Lowe, K. Power, M. Marsan. 1996. *Canada's forest inventory 1991: summary by Terrestrial Ecozones and Ecoregions*. Natural Resources Canada, Canadian Forest Service, Victoria. Information Report BC-X-346E.
[15] Statistics Canada. 2001. *Econnections: Linking the Environment and the Economy*: Indicators and Detailed Statistics. Cat. No. 16-200-XKE, February 2001, Ottawa http://www.statcan.ca/english/IPS/Data/16-200-XKE.htm
[16] The growth rate is based on Canada's Forest Inventory 1991. The Canadian Forest Service publication Bickerstaff, A. *et al*. 1981. *Growth of Forests in Canada. Part 2: A Quantitative Description of the Land Base and the Mean Annual Increment*. Can. For. Serv. Infor. Rep. PI-X-1 provides national level growth rates for Rowe's Forest Regions.
[17] According to Daryl Price of Alberta LFS, this may be a very simplistic approach given that the provincial roll up of inventory is for the gross land base (i.e., all forested stands regardless of merchantability potential or access restriction/constraints) and timber harvest occurs on the net land base. At best, Price suggests, our estimates are a very crude proxy. He suggests that depletions are likely double-counted in the timber accounts as several are already accounted for in LFS net area and yield curves. (Daryl Price provided written comments dated January 15, 2001 on an earlier draft of this report.)
[18] Personal conversation with Daryl Price of the Alberta Forest Service, November 20,2000
[19] According to written comments from Daryl Price (Jan. 15, 2001), a significant portion of required wood supply will come from gaining coniferous and deciduous volumes by managing Crown forest lands as a single land base rather than the current split between coniferous and deciduous land bases. Residual wood chips also play a significant role. Most wood from private land harvest is due to liquidation for agriculture.

[20] As Daryl Price noted in his written comments of January 15, 2001, "Growth needs to be tracked on the total gross forest land base recognising that AAC determination and sustainable timber harvest tracks along the net forest land base. The important concept is that all of the calculations must be made for the same timber/area/land base."

[21] Alberta Environmental Protection (1996). *The Status of Alberta's Timber Supply*. Edmonton, May 1996.

[22] Anielski, Mark (1992). *Resource Accounting: Indicators of the Sustainability of Alberta's Forest Resources.* Paper presented at the International Society of Ecological Economics meeting in Stockholm, Sweden, August 1992.

[23] Daryl Price of Alberta LFS (as per January 15, 2001 written comments on an earlier draft of this report) notes that "A provincial roll up of the median and average volume is not determined on an annual basis. Volumes are currently determined within each FMA or FMU and are the basis on which sustainable AACs are determined. Previously, volumes were derived primarily (with the exception of the older FMAs) from the provincial volume sampling region (VSR) based cover type volume tables developed under the Phase 3 inventory. Similar to the Phase 3 versus AVI age class roll up situation, and given the number of yield strata being modeled in timber supply analysis for each FMA, LFS does not have a direct roll up of the average yield by FMA that can be area weighted to a provincial level that accounts for the differences between the gross and net land bases. The summary provided by LFS was derived from the Phase 3 database (compilation was completed in 1998) based on the VSR cover type volume tables. This summary identifies the average volume and total area within each VSR, cover group, height and density class combination. The current minimum merchantability standard for harvest is 50 m3/ha @ 15+/11 cm utilization. Actual harvest means are difficult to determine as conifer and deciduous volumes are often harvested from the same hectare of land: e.g., deciduous harvested as a result of conifer operations in mixedwood stands and conifer harvested as a result of deciduous operations in " pure" deciduous stands. In summary the differences in provincial growth rates are attributable to: 1) the model used by Statistics Canada; 2) the net versus gross area " average" production the mixing of data sets."

[D.] Price (January 15, 2001) notes that there is an inherent weakness in translating the area and volume components that can result in faulty conclusions with respect to data and how it is presented (i.e. mixing of qualitative and quantitative factors).

[25] D. Price of the Alberta LFS noted that the creation of such a longitudinal timber volume account where closing inventory statistics are balanced on an annual basis is problematic given that this approach is consistent with the LFS approach to estimating AACs (annual allowable cut) and where harvest volumes are balanced over a 5-year period.

[26] Organisation for Economic Co-operation and Development (1994). *OECD Core Set of Environment Indicators Forest Resources: Measurement Issues.* Draft working Paper on the Group on the State of the Environment. September 1994, Paris.

[27] According to comments by Daryl Price of Alberta LFS in his January 15, 2001 review of this paper, he noted that the impacts of fire, insects and land deletions "may also be accounted for directly in AAC calculation by the FMAs (Forest Management Agreement holders, i.e., forestry companies)" accounted for in their periodic re-planning of AACs at the FMA level. He also noted that " Harvesting is not a permanent depletion. Fire, insect and disease, and natural mortality are accounted for "implicitly." Oil and gas and agriculture are accounted for "explicitly" in AAC calculations." What is meant by "implicit" accounting is not clear. We can only suggest that a more transparent accounting system is desirable, one that clearly shows the assumptions and detailed data that makes up the AAC calculation.

[28] From written comments from January 15, 2001 on an earlier draft of this report.

[29] ALCES® is a fast user-friendly internet-delivered landscape simulator that enables resource managers, society, and the scientific community to explore and quantify dynamic landscapes subjected to single or multiple human landuse practices and various natural disturbance regimes (such as fire). ALCES was developed by Dr. Brad Stelfox of FOREM Technologies, see http://www.foremtech.com/products/pr_alces.htm

[30] *The State of Canada's Forests 1998-1999*. Natural Resources Canada, Ottawa. p. 31

[31] Statistics Canada. *Econnections 2000*. Alberta timber account tables. Personal conversation with Gerry Gravel, Statistics Canada.

[32] Daryl Price in written commentary January 15, 2001 on an earlier draft of this report.

[33] Price explains, " The original White Area AVI was previously aggregated to look like the Phase 3 inventory classification and was included in the 1991 summary. Unfortunately LFS does not have a

corresponding summary for the 1991 timeframe that is based on the Green Area only. There is an approximate difference in productive/potentially productive area between 1.3 to 1.5 million ha based on what LFS can piece together from hard copy reports run in the early 1990s; it is difficult to quantify the exact difference given the back and forth transfer of White to Green Area and vice versa that has occurred in the intervening years."

[34] ibid.

[35] Despite input and discussions with Daryl Price of Alberta LFS and with Rick Moll of Statistics Canada, we were unable to reconcile the data differences. Alberta LFS considers their figures accurate given they actually map the areas harvested (with the exception of the White Area). The discrepancies between data sets may be for many reasons including differences in reporting times. Another issue may be how residual chips from sawmills are accounted for in Statistics Canada figures.

[36] Input from Daryl Price, January 15, 2001.

[37] Peter Lee and Kevin Timoney. 2000. *Economic Growth Driven by Resource Development Leads to Ecosystem Degradation: Alberta, Canada, A Case Study*. Unpublished working paper.

[38] Alberta Environmental Protection. 1998. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region*," Natural Heritage Planning and Evaluation. Branch, March 19998 Protected Areas Report no. 13 (report prepared by Richard Thomas), Summary p. iv. According to Daryl Price, in written comments on a previous draft report on January 15, 2001, he noted that very little of the dry mixedwood forest has been deforested for agriculture use and very little (only 23%) of the area is in the " Green Area" (i.e., public forest land).

[39] Alberta Environmental Protection. 1998. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region*," Natural Heritage Planning and Evaluation Branch, March 19998 Protected Areas Report no. 13 (report prepared by Richard Thomas), p. 17.

[40] Alberta Environmental Protection, 1996. *Selecting Protect Areas: The Foothills Natural Region of Alberta*, p.26.

[41] Alberta Environmental Protection.1998. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region*, Natural Heritage Planning and Evaluation

[42] World Resources Institute. 2000. *Canada's Forests at a Crossroads: An Assessment in the Year 2000*. A Global Forest Watch Canada Report, Washington.

[43] B.A. Wilcox and D.D. Murphy. *Conservation Strategy: The effects of fragmentation on extinction*, American Naturalist, 125, 879-887, 1985, cited in *The Foothills Natural Region of Alberta*, 1996, p.11

[44] Alberta Environmental Protection. 1998. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region*," Natural Heritage Planning and Evaluation Branch, March 19998 Protected Areas Report no. 13 (report prepared by Richard Thomas), pp. 77 and 80.

[45] Peter Lee and Kevin Timoney. 2000. *Economic Growth Driven by Resource Development Leads to Ecosystem Degradation: Alberta, Canada, A Case Study*. Unpublished working paper.

[46] Data from Alberta Energy and Utilities Board website at www.eub.gov.ab.ca

[47] According to Daryl Price of Alberta LFS in written commentary January 15,2001 these figures are not necessarily additive. For example, a road, a pipeline and a powerline may be side by side (thus reducing the total clearing area) and almost always use an existing seismic line. This may, according to Price, lead to double and triple counting of areas in some cases.

[48] Hardy Associates (1978) Ltd. 1981. *Forest Depletion by Energy Development in the Green Area of Alberta*, prepared for Alberta Energy and Natural Resources.

[49] Hardy Associates (1978) Ltd. 1981. *Forest Depletion by Energy Development in the Green Area of Alberta*, prepared for Alberta Energy and Natural Resources, p. 21

[50] Hardy Associates (1978) Ltd. 1981. *Forest Depletion by Energy Development in the Green Area of Alberta*, prepared for Alberta Energy and Natural Resources, pp. 22-24.

[51] The Environment Council of Alberta. 1979. *The environmental effects of forestry operations in Alberta – Report and Recommendations*. Environment Council of Alberta, Edmonton.

[52] Hardy Associates (1978) Ltd. 1981. *Forest Depletion by Energy Development in the Green Area of Alberta*, prepared for Alberta Energy and Natural Resources, p. 37.

[53] Alberta Environmental Protection.1998. *The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region*, Natural Heritage Planning and Evaluation, p. 82.

[54] Alberta Energy and Utilities Board, Field Surveillance April 1998/March 1999. Energy and Utilities Board, Statistical Series 57.

[55] Alberta Environmental Protection. 1996. *Selecting Protected Areas: The Foothills Natural Region of Alberta*, Alberta Environmental Protection.
[56] Alberta Environmental Protection. 1996. *Selecting Protected Areas: The Foothills Natural Region of Alberta*, Alberta Environmental Protection, pp. 17-18.
[57] Alberta Environmental Protection. 1996. *Selecting Protected Areas: The Foothills Natural Region of Alberta*, Alberta Environmental Protection, p. 15.
[58] Daryl Price, Alberta LFS in written comments January 15, 2001.
[59] Daryl Price, Alberta LFS in written comments January 15, 2001.
[60] Daryl Price, Alberta LFS in written comments January 15, 2001.
[61] Daryl Price, Alberta LFS in written comments January 15, 2001.
[62] Daryl Price, Alberta LFS in written comments January 15, 2001.
[63] World Resources Institute www.wri.org/wri/wr2000/forests_scorecard.html
[64] Alberta Environmental Protection. 1996. *Selecting Protected Areas: The Foothills Natural Region of Alberta*, Alberta Environmental Protection.
[65] *The 1996 Status of Wildlife in Alberta* report is available at http://www3.gov.ab.ca/srd/fw/status/. A more recent 2000 report has recently been released.
[66] Alberta Environmental Protection. 1996. *Selecting Protected Areas: The Foothills Natural Region of Alberta*, Alberta Environmental Protection. p. 34.
[67] Alberta Environmental Protection. 1996. *Selecting Protected Areas: The Foothills Natural Region of Alberta*, Alberta Environmental Protection, p. 36.
[68] Dr. Brian Horesji, personal communication, August 2000.
[69] Nagy, J.A. and J.R. Gunson. 1990. Management Plan for Grizzly Bears in Alberta. Alberta Forestry, Lands and Wildlife, Wildlife Management Planning Series No. 2.
[70] Committee on the Status of Endangered Wildlife in Canada, *Results of COSEWIC Species Assessments*, COSEWIC, May 2000.
[71] Boreal Caribou Research Program, http://www.deer.rr.ualberta.ca/caribou/bcrp.htm
[72] Alberta Environmental Protection. 1996. *Selecting Protected Areas: The Foothills Natural Region of Alberta*, Alberta Environmental Protection.
[73] Dyer, Simon. 1999. *Movement and distribution of woodland caribou in response to industrial development in northeastern Alberta*, M.Sc., University of Alberta, Edmonton.
[74] James, Adam R.C. 1999. *Effects of Industrial Development on the Predator-Prey Relationship Between Wolves and Caribou in Northeastern Alberta*., Ph.D. thesis, University of Alberta, Fall,1999.
[75] According to Alberta LFS's Daryl Price, " The regeneration status (for purposes of national level reporting) is defined in terms of nine classes which relate to the level of stocking of commercial tree species, their distribution and the degree to which they are affected by competing vegetation. The classes are usually aggregated for presentation to non-specialist audiences. The two primary classes are defined as: *Understocked* - Disturbed forest land that will require silvicultural treatment to meet stocking standards. This class includes harvested areas that do not contain enough young trees to meet a province's or territory's stocking standards. Natural regeneration could eventually meet stocking standards, but this process would take a long time. *Successfully Regenerated* - Disturbed areas that have regenerated naturally or through planting and seeding. This class includes some recently disturbed areas that are expected to regenerate within an acceptable time without further silvicultural treatment.)"
[76] Anielski, Mark. 1996. "Accounting for the Sustainability of Alberta's Forests – The 1995 Timber Resource Account." Alberta Treasury. Unpublished paper.
[77] World Resources Institute www.wri.org/wri/wr2000/forests_scorecard.html
[78] World Resources Institute www.wri.org/wri/wr2000/forests_scorecard.html
[79] based on input by Daryl Price January 15, 2001 in written comments on an earlier draft of the Alberta GPI forestry report.
[80] World Resources Institute. 2000. *Canada's Forests at a Crossroads: An Assessment in the Year 2000*. A Global Forest Watch Canada Report, Washington, (see Map 2 and p. 25)
[81] World Resources Institute www.wri.org/wri/wr2000/forests_scorecard.html
[82] Sedjo, R. 1993. "The Carbon Cycle and Global Forest Ecosystems," in *Water, Air, and Soil Pollution. August 1993, and in Terrestrial Biospheric Carbon Fluxes: Quantification of Sinks and Sources of* CO_2, Joe Wisniewski and R. Neil Sampson (eds.), pp. 295-309, Kluwer Academic Publishers, Boston, 1993.
[83] Daryl Price of the Alberta LFS suggests these values are uncertain and open to debate.

[84] Van Kooten, G.C., Louise M. Arthur and W.R. Wilson (1992). "Potential to Sequester Carbon in Canadian Forests: Some Economic Considerations." *Canadian Public Policy*, June 1992.
[85] Anielski, Mark. 1998. *In Search of the Carbonic Truth: Carbon Accounting*. Paper presented at the Parkland Institute, November 14 1998 conference, Edmonton, Alberta.
[86] Anielski, Mark. 1992. *Accounting for Carbon Fixation by Alberta's Forests and Peatlands*. Presented at the Second Meeting of the International Society of Ecological Economics (ISEE) " Investing in Natural Capital - A Prerequisite for Sustainability," Stockholm, Sweden. August 3-6, 1992.
[87] Pearce, F. 1999. "That sinking feeling." *New Scientist* 164 (2209): 20-21.
[88] Haener, M.K., and W.L. Adamowicz. 2000. "Regional forest resource accounting: a northern Alberta case study," *Can. J. For. Res*. 30: 264-273. and Hartwick, J.M. 1990. "Natural resources, national accounting and economic depreciation," *J. Public Econ*. 43: 291-304.
[89] Anielski, Mark and Jonathan Rowe. 1999. *The Genuine Progress Indicator – 1998 Update*. Redefining Progress, San Francisco. March 1999. http://www.rprogress.org/pubs/pdf/gpi1998_data.pdf
[90] Hamilton, C. and R. Denniss. 2000. *Tracking Well-being in Australia, The Genuine Progress Indicator 2000*. The Australia Institute. Number 35. December 2000.
[91] Gale, G., F. Gale, and T. Green. 1999. *Accounting for the Forests: A Methodological Critique of PriceWaterhouse's Report "The Forest Industry in British Columbia 1997."* Produced for the Sierra Club of Canada by Ecological Economics Inc. Victoria, B.C.
[92] AFPA. 1999. *Economic Impact and Analysis*. Alberta Forest Products Association. Edmonton, Alberta. www.abforprod.org
[93] Gale, R., F. Gale, and T. Green. 1990. *Accounting for the Forests: A Methodological Critique of PriceWaterhouse's Report "The Forest Industry in British Columbia 1997*." Produced for the Sierra Club of Canada by Ecological Economics Inc., Victoria, B.C.
[94] Gale, R., F. Gale, and T. Green. 1990. *Accounting for the Forests: Methodological Critique of Price Waterhouse's Report "The Forest Industry in British Columbia 1997."* Produced for the Sierra Club of Canada by Ecological Economics Inc., Victoria, B.C.
[95] Haener, M.K., and W.L. Adamowicz. 2000. "Regional forest resource accounting: a northern Alberta case study," *Can. J. For. Res*. 30: 264-273. and Hartwick, J.M. 1990. "Natural resources, national accounting and economic depreciation," *J. Public Econ*. 43: 291-304.
[96] Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. "The value of the world's ecosystem services and natural capital," *Nature*. 387: 253-259.
[97] Anielski, Mark (1991). *Forest Economic Rents in Alberta: Efficient and Equitable Treatment*, Masters of Science Thesis, Department of Rural Economy, University of Alberta, Edmonton.
[98] Statistics Canada uses a net present value approach to estimating economic rent from timber capital harvest whereby a five-year moving average rent figure is calculated then applied to the timber capital volume accounts to estimate the mo netary value of both stock and flow data. We attempted to " unbundle" the five-year moving average rent estimates to estimate an annual economic rent per cubic metre to apply to our GPI forest accounts, then converted these figures to 1998 constant dollars. Gerry Gravel of Statistics Canada explains " You can derive per-unit rent using the value series. The stock value is based on a lagged 5-year moving average harvest value. The average harvest value is simply divided by an interest rate (4%) to get the stock value. You could undo the calculation by 1) multiplying by .04, which would leave the current average annual rent. To get per-unit rent, you could divide by the average annual harvest volume of the relevant five-year period." (personal email conversation September 14, 2000).
[99] Employment (direct) statistics are from Statistics Canada Cat. #25-202, Census of Manufacturers for Alberta, forestry (logging), wood industries and pulp and allied industries, 1961 to 1997. 1998 and 1999 figures are estimated based on the average employment growth rate of 7.6% per annum from 1987 to 1997 for total forest industry.
[100] Anielski, Mark and Jonathan Rowe. 1999. *The Genuine Progress Indicator – 1998 Update*. Redefining Progress, San Francisco. March 1999. http://www.rprogress.org/pubs/pdf/gpi1998_data.pdf
[101] Hamilton, C. and R. Denniss. 2000. *Tracking Well-being in Australia, The Genuine Progress Indicator 2000*. The Australia Institute. Number 35. December 2000.