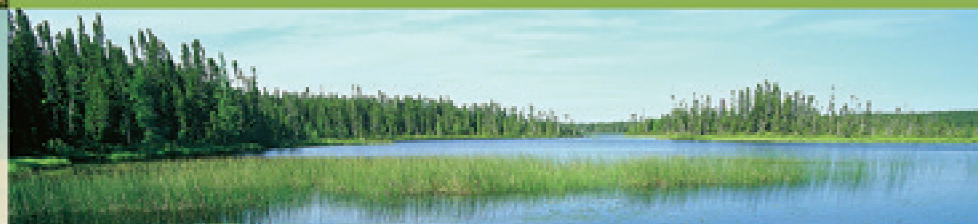
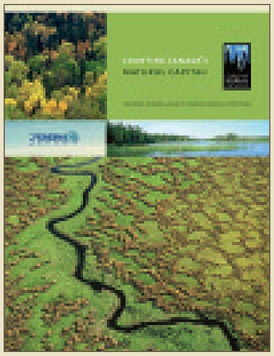
COUNTING CANADA'S NATURAL CAPITAL:

CANADIAN BOREAL INITIATIVE

ASSESSING THE REAL VALUE OF CANADA'S BOREAL ECOSYSTEMS

the PEMBINA institute





All cover photos: Garth Lenz

Counting Canada's Natural Capital:

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About the Canadian Boreal Initiative

The Canadian Boreal Initiative was created in response to both the opportunities and threats facing Canada's Boreal region.

Based in Ottawa, the CBI brings together a wide range of conservation organizations, First Nations, industry leaders and others to create new solutions for Boreal conservation and sustainable development. It supports scientific research to advance thinking on conservation-based planning for the Boreal region, and acts as a catalyst by supporting a variety of on-the-ground efforts across the Boreal by conservation groups, First Nations and others.

In 2003 the CBI convened the Boreal Leadership Council, an extraordinary group of conservation organizations, First Nations and resource companies. In concert with the members of the council, the CBI created and launched the Boreal Forest Conservation Framework – a vision for the protection and sustainable development of Canada's entire Boreal ecosystem.

www.borealcanada.ca

About the Pembina Institute

The Pembina Institute is an independent, not-for-profit environmental policy research and education organization. Founded in Drayton Valley, Alberta, the Pembina Institute has a multidisciplinary staff of more than thirty, with offices in Drayton Valley, Calgary, Edmonton, Vancouver, Ottawa and Toronto.

The Pembina Institute's major policy research and education programs are in the areas of sustainable energy, climate change, environmental governance, ecological fiscal reform, sustainability indicators, and the environmental impacts of the energy industry.

www.pembina.org

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Mark Anielski is an ecological economist, entrepreneur, professor, author, and president of his own consulting firm, Anielski Management Inc., which specializes in measuring the sustainability and well-being of communities and organizations. Since the early 1990s, Mark has been pioneering the development of natural capital accounting systems in Alberta and Canada and is currently a senior adviser to the Chinese Government on green gross domestic product (GDP) accounting for China. He has considerable experience in public policy analysis of natural resource, energy, royalty, and fiscal policy issues in both the public (Alberta Government) and private (GPC—Government Policy Consultants) sectors. His expertise is varied and broad; it includes accounting for sustainable development, natural resource accounting, public policy analysis, business planning, and performance measurement.

Garth Lenz

From 2000 to 2003, he served on the National Round Table on the Environment and the Economy and the Environment and Sustainable Development Indicators Steering Committee, which developed the first set of sustainable and environmental performance indicators for Canada. Mark teaches corporate social responsibility at the University of Alberta's School of Business. He also teaches a course in sustainable economics at the Bainbridge Graduate Institute near Seattle—the first MBA program in sustainable business practices and ethics. Prior to starting his own consulting practice, Mark spent 14 years as senior policy adviser to the Alberta Government in the ministries of Treasury, Environment, and Forestry, Lands, and Wildlife, conducting economic analysis of environmental policies. From 1995 to 1999, he was part of Alberta Treasury's performance measurement team, which designed and implemented Alberta's internationally recognized performance measurement system (Measuring Up) and three-year government business planning process. Since leaving the Alberta Government in 1999, he has dedicated his work life to developing alternative measures of economic progress, such as the US Genuine Progress Indicator (GPI), the Alberta GPI Sustainable Well-being Accounting System, Ecological Footprint Analysis, and other quality-of-life indicator systems.

His new Genuine Wealth model, which provides an accounting framework for measuring and managing the total human, social, and natural wealth of communities, is currently in development. Mark is president of the Canadian Society for Ecological Economics, a Senior Fellow with the Oakland-based economic think-tank Redefining Progress, and an associate of the Pembina Institute for Appropriate Development.

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Sara Wilson is an independent research and policy analyst who has worked as a consultant for over five years. She specializes in the areas of socio-economic analysis of environmental data—notably ecosystem valuation and full cost accounting techniques, public policy development, ecological fiscal reform, and environmental management. She has compiled, analyzed, and developed social, economic, and environmental indicators for provincial accounting purposes, and developed market and non-market valuations for ecosystem services such as carbon sequestration and water quality. Sara has also developed environmental policy alternatives, including initiatives that address climate change, pollution prevention, ecosystem conservation, and ecological fiscal reform.

Garth Lenz

Sara was a lead author on the first provincial Genuine Progress Indicator (GPI), namely the Alberta Sustainability Index—a set of social, environmental, and economic accounts that evaluate the sustainability of Alberta's natural, social, and human capital; and the Nova Scotia GPI (i.e., The State of Nova Scotia's Forests: Ecological, Social and Economic Values of Nova Scotia's Forests). She has also authored an assessment of the measures of community well-being proposed for land-use planning in the Central Coast, North Coast, and Haida Gwaii/Queen Charlotte Islands; and the GPI accounts on forests and water quality.

Sara has training in environmental economics from the Smithsonian Institution in Washington, DC, and a background in economic applications such as cost-benefit analysis and full cost accounting. For example, she has authored The Costs and Benefits of Sewage Treatment and Source Control for the Halifax Harbour and The GPI Water Quality Accounts in Nova Scotia.

Sara has provided research and policy development services for the National Round Table on the Environment and the Economy, the Pembina Institute for Appropriate Development, Genuine Progress Index for Atlantic Canada, the David Suzuki Foundation, Rainforest Solutions Project, the Canadian Boreal Initiative, and the Green Budget Coalition. As a result, her work includes projects in the forestry, energy, fisheries, agriculture, and mining sectors in Canada.

Sara has a master's degree in Science in Forestry (Mixed Boreal Forest Disturbance Ecology), a certificate in Economics and Policy Solutions for Ecosystem Conservation, and a bachelor's degree (honours) in International Development Studies and Environmental Geography. Sara currently lives in Victoria, BC, with her husband, Faisal, and their two children.

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Our special thanks extend to Peter Lee and staff of Global Forest Watch Canada, whose tireless commitment to this project and superb spatial analysis skills made it possible for us to complete a preliminary accounting of some of the key attributes of the boreal region's natural wealth. This study would not have been possible without the helpful input to an earlier draft from our advisers, reviewers, and contributors. They include Dr. David W. Schindler (University of Alberta), Dr. Fiona Schmiegelow (University of Alberta), Tom Green (Rainforest Solutions Project), Kelvin Hirsch (Canadian Forest Services), Steven Gray (Canadian Forest Services), Dr. Vince St. Louis (University of Alberta), Dr. Nancy Olewiler (Simon Fraser University), Heather Johannesen (Atlantic Institute for Sustainability), Dr. Robert Costanza (Gund Institute for Ecological Economics, University of Vermont), Ed Banfield (Natural Resources Canada), Mark Gillis (Canadian Forest Services), Alexis Morgan (World Wildlife Fund), Kevin Kavanagh (World Wildlife Fund), Rick Moll (Statistic Canada), Gerry Gravel (Statistic Canada), Robert Smith (Statistic Canada), Gary Stewart (Ducks Unlimited Canada), Glenn Mack (Ducks Unlimited Canada), Silvie Forest (Ducks Unlimited Canada), Chris Smith (Ducks Unlimited Canada) Dr. Werner Kurz (Ducks Unlimited Canada), Dr. Casey van Kooten (University of Victoria), Dr. Peter Boxall (University of Alberta), Bruce Macnab (Sustainable Forest Research Network, University of Alberta), Dr. Viktor Adamowicz (University of Alberta), and Dr. Josh Farley (University of Vermont).

Several recent publications contributed greatly to this study, including (1) Dr. Nancy Olewiler's The Value of Natural Capital in Settled Areas of Canada (2004), a report commissioned by Ducks Unlimited Canada with the support of the Nature Conservancy Canada; (2) Peter Lee's Boreal Canada: State of the Ecosystem, State of Industry, Emerging Issues and Projections (Report to the National Round Table on the Environment and the Economy) (2004), and;(3) the Canadian Boreal Initiative's The Boreal in the Balance: Securing the Future of Canada's Boreal Region (2005).

This study is dedicated to Dr. Herman Daly, one of the founders of ecological economics.

Disclaimer

This first beta account of Canada's boreal region wealth is constrained primarily by the lack of publicly available data or inventory on the physical and qualitative state of the boreal region's numerous natural capital assets and ecological goods and services. Notwithstanding, Global Forest Watch Canada's spatial analysis of the human and industrial ecological footprint or pressures and the natural disturbance regime on the boreal ecosystem made a preliminary boreal wealth account possible. This study is clearly only the first step or baseline for a more comprehensive and complete accounting of the boreal region's ecological wealth.

The content of this study is the responsibility of its two authors and does not necessarily reflect the views and opinions of those who are acknowledged above.

We made every effort to ensure the accuracy of the information contained in this study at the time of writing. However, the authors advise that we cannot guarantee the information provided herein is complete or accurate and, thus, any person relying on this study does so at his or her own risk. While the study received some peer review, the review was limited by the time constraints of our reviewers. The material should thus be viewed as preliminary, and we welcome suggestions for improvements that can be incorporated in any later edition of the study.


Garth Lenz

Table of Contents

Figures and Tables

Foreword

"...it lies within the power of human societies to ease the strains we are putting on the nature services of the planet, while continuing to use them to bring better living standards to all. Achieving this, however, will require radical changes in the way nature is treated at every level of decision-making and new ways of cooperation between government, business and civil society. The warning signs are there for all of us to see. The future now lies in our hands."

– Statement issued by the board of directors that oversaw the 2005 Millenium Ecosystem Assessment Report, co-chaired by Dr. Robert Watson, chief scientist of The World Bank and Dr. A. H. Zakri, director of the United Nations University's Institute of Advanced Studies

At 1.4 billion acres, Canada's Boreal region is one of the last and largest intact forests left in the world. Boreal ecosystems buffer us against the effects of climate change because its soils and peatlands form the largest terrestrial carbon storehouse on the planet-larger even than the rainforests.

Precisely because boreal forests are such large storehouses for carbon, forest management practices and changes in boreal forest cover can also be significant sources of greenhouse gas emissions. Yet the importance of managing forest carbon reservoirs has received only limited recognition in efforts to combat climate change. Looking beyond the current Kyoto Protocol, we will need every measure at our disposal in our global effort to address and adapt to climate change. That means including all forests in any long-term climate change regime, and building experience with forest carbon management even now.

This is only one of many examples of how the true value of ecosystem services are not being adequately integrated into policy decisions. As outlined in this report, we are only just beginning to understand the true value of these services, including flood control, water filtration, climate regulation, and even pest control.

Better yet, we have an opportunity to get it right in Canada's boreal. We can sustain its natural capital and the ecosystem services it provides while building other forms of wealth and maintaining community and cultural values.

Natasha Moine

It's in response to this unique opportunity that the Canadian Boreal Initiative launched the Boreal Forest Conservation Framework and is working with leading companies, with Aboriginal communities and with conservation groups across the country to promote a balanced approach to conservation - one that is based on protection of at least half of the landscape and world-class economic development on the remaining lands.

Central to the Framework is ensuring that there is thoughtful and comprehensive, conservation-based land use planning prior to resource management decisions being made. And in order to take this approach effectively, there is a need to have the most complete information possible about values that are important and possible impacts of decisions under consideration.

The extraordinary values set out in this report and the BEWAS framework it introduces can only hasten our progress. Our hope is that the BEWAS becomes an international benchmark and an important tool for measuring the conditions and economic values of Canada's ecosystems, in general, and the Boreal region in particular. An understanding of the Boreal region's true value is essential to addressing important questions about how ecosystem conservation can continue to contribute to national and global well-being for generations to come.

Cathy Wilkinson
Canadian Boreal Initiative

EXECUTIVE SUMMARY

Garth Lenz

The UN's Millennium Ecosystem Assessment report *Ecosystems and Human Well-being* (2005) pointed to the urgency of diagnosing the conditions of the world's ecosystems, conserving their integrity and capacity to provide sustained ecosystem services for human and ecological well-being, and appreciating their true and full economic value. The UN found that approximately 60 percent of the ecosystem services of the world's ecosystems are being degraded or used unsustainably, including fresh water, capture fisheries, air and water purification, and the regulation of regional and local climates, natural hazards, and pests.

The report also noted that in many regions, little is known about the status and economic value of ecosystem services. Ironically, despite their importance to human well-being, the depletion or degradation of ecosystem services and natural capital, in general, is rarely tracked in national economic accounts and is unaccounted for in measures of economic progress, like the gross domestic product (GDP).

The primary purpose of our two-year study is to begin to identify, inventory, and measure the full economic value of the many ecological goods and services provided by Canada's boreal region, which covers 58.5 percent of Canada's land mass. For this purpose, we developed the Boreal Ecosystem Wealth Accounting System (BEWAS), a tool for measuring and reporting on the physical conditions and the full economic value of the boreal region's natural capital and ecosystem services.

We use the term *natural capital* to refer to the resources, living systems, and ecosystem services provided by Earth's biosphere, including the ecological systems that support life. Ecosystem services are produced by interactions within the dynamic complex of plants, animals, microbes, and physical environmental features that make up an ecosystem. These services are referred to as the benefits that humans obtain from ecosystems.

Canada's boreal region provides a range of ecosystem goods and services; these include timber from forests, oil and gas, and hydroelectricity, and the plethora of ecosystem services provided by wetlands and forests such as purifying water, regulating climate, and producing oxygen. While the market benefits of harvesting timber or extracting oil and gas are measured in terms of their contribution to Canada's GDP, the value of most of the boreal region's ecosystem services is unnoticed, unconsidered, and unvalued in the GDP and Canada's national income accounts. There is no line in the nation's balance sheet for natural capital.

Ignoring the value of Canada's boreal wealth to the well-being of the nation is akin to Exxon-Mobil ignoring the volume of oil and gas reserves and annual production in its annual report. Yet this is how nations treat their natural capital, by disregarding its full economic value.

A nation could cut down its forests, deplete its oil reserves, drain its wetlands, and degrade groundwater aquifers, and the primary measure of economic progress—the GDP—would either ignore the environmental depreciation costs of economic growth or, even worse, treat the depleted natural capital as an added asset. It seems that only when an ecosystem has been damaged or irreversibly degraded is its economic value considered, based on the financial costs of replacing no-priced ecosystem services with expensive human-built infrastructure.

This study reveals the broad range of ecological goods and services provided by Canada's boreal region. These have been organized into a BEWAS. The purpose of the BEWAS is to give Canadian decision makers a boreal natural capital "balance sheet" for assessing the sustainability, integrity, and full economic value of the boreal region. The balance sheet is broken down into three main accounting categories:

1. *Natural capital accounts*—including the stocks, flows, and monetary values (market and non-market values) of forests, mineral and energy resources, fish and wildlife, wetlands and peatlands, and water resources (lakes, rivers)
2. *Land accounts*—including an account of land area by land type such as forest land, agricultural land, wetlands, and peatlands
3. *Ecosystem service accounts*—including atmospheric stabilization; climate stabilization; disturbance avoidance; water stabilization; water supply; erosion control and sediment retention; soil formation; nutrient cycling; waste treatment; pollination; biological control; habitat; raw materials; genetic resources; and recreation and cultural use. As noted, most of these ecosystem services go unaccounted for in conventional economic decision making.

Using the BEWAS as an analytic and reporting framework, this study begins to estimate some of the economic value of the boreal region's many ecological goods and services. The purpose of such valuation work is to provide decision makers with a means of considering the full economic value of the many ecological goods and services of the boreal region when making decisions about its future.

The results of the preliminary economic valuation estimates of the boreal region are summarized in Table 1. We have estimated the ***annual*** market values of natural capital extraction and the non-market values of ecosystem services in the boreal region for 2002. The market values associated with the use of some of the boreal region's natural capital resources (e.g., timber, minerals, water) are calculated based on estimates of the contribution their extraction makes to Canada's GDP, adjusted for some of the environmental and societal costs associated with natural resource extraction.

The estimated **net market value of boreal natural capital extraction in the year 2002 is $37.8 billion**. If accounted for, boreal natural capital extraction would equate to 4.2 percent of the value of Canada's GDP in 2002. The net market value calculation is based on the contribution to Canada's GDP from boreal timber harvesting; mineral, oil and gas extraction; and hydroelectric generation ($48.9 billion; or $83.63 per hectare of the boreal ecosystem land base) minus the estimated $11.1 billion in environmental costs (e.g., air pollution costs) and societal costs (e.g., government subsidies) associated with these industrial activities.

We have also estimated the non-market values of a small subset of boreal ecosystem services, including the economic value of carbon sequestration by forests and peatlands, nature-related recreation, biodiversity, water supply, water regulation, pest control, non-timber forest products, and Aboriginal subsistence values.

The estimated **total non-market value of boreal ecosystem services in the year 2002 is $93.2 billion** (or $159 per hectare of the boreal ecosystem land base). If accounted for, boreal ecosystem services would equate to 8.1 percent of the value of Canada's GDP in 2002.

The ecosystem services with the highest economic value per year are (1) flood control and water filtering by peatlands—$77.0 billion; (2) pest control services by birds in the boreal forests—$5.4 billion; (3) nature-related activities—$4.5 billion; (4) flood control, water filtering, and biodiversity value by non-peatland wetlands—$3.4 billion; and (5) net carbon sequestration by the boreal forest-$1.85 billion.

When we compare the market and non-market values for the year 2002, **the total non-market value of boreal ecosystem services is 2.5 times greater than the net market value of boreal natural capital extraction**. This result is significant. It suggests that the ecological and socio-economic benefits of boreal ecosystem services, in their current state, may be significantly greater than the market values derived from current industrial development—forestry, oil and gas, mining, and hydroelectric energy—combined.

Table 1: Summary of Natural Capital Economic Values for Canada's Boreal Region

Boreal Ecosystem Wealth *Natural Capital* Accounts	Monetary Economic Values and Regrettable Costs[a] (2002$ per annum)[b]
Forests	**Market values:** • $14.9 billion in estimated market value of forestry-related GDP in the boreal region (est. 2002) **Costs:** • $150 million in estimated cost of carbon emissions from forest industry activity in the boreal region (deduction against forestry-related GDP) **Non-market values:** • $5.4 billion in value of pest control services by birds • $4.5 billion for nature-related activities • $1.85 billion for annual net carbon sequestration (excludes peatlands) • $575 million in subsistence value for Aboriginal peoples • $79 million in non-timber forest products • $18 million for watershed service (i.e., municipal water use) • $12 million for passive conservation value
Wetlands and peatlands	**Non-market values:** • $77.0 billion for flood control and water filtering by peatlands only • $3.4 billion for flood control, water filtering, and biodiversity value by non-peatland wetlands • $383 million for estimated annual replacement cost value of peatlands sequestering carbon
Minerals and subsoil assets	**Market values:** • $14.5 billion in GDP from mining, and oil and gas industrial activities in the boreal region (est. 2002) **Costs:** • $541 million in federal government expenditures as estimated subsidies to oil and gas sector in the boreal region • $474 million in government expenditures as estimated subsidies to mining sector in the boreal region
Water resources	**Market values:** • $19.5 billion in GDP for hydroelectric generation from dams and reservoirs in the Boreal Shield ecozone (est. 2002)
Waste production (emissions to air, land, and water)	**Costs:** • $9.9 billion in estimated air pollution costs to human health[c]
TOTAL market values (forestry, mining, oil and gas industrial activity, and hydroelectric generation)	$48.9 billion
Less cost of pollution and subsidies: • Air pollution costs • Government subsidies to mining sector • Federal government subsidies to oil and gas sector • Forest sector carbon emission costs	 – $9.9 billion – $474 million – $541 million – $150 million
NET market value of boreal natural capital extraction	$37.8 billion
TOTAL non-market value of boreal ecosystem services	$93.2 billion
RATIO of non-market to market values	2.5

Note: Market values are denoted in blue; non-market values in green and environmental/societal costs in brown.

a These are either environmental or societal costs associated with market-based activities (e.g., forest industry operations).

b A GDP chained, implicit price index was used throughout the study to standardize to 2002 dollars.

c Based on European Union air pollution cost estimates for SO_2, NO_x, $PM_{2.5}$, and VOC for 2002.

Garth Lenz

Key Findings

The following are the key highlights of our study and analysis.

The results of the estimated **net market value of boreal natural capital extraction** for 2002 include:

- Canada's boreal forest contributed an estimated $14.9 billion to Canada's GDP from harvested timber (based on estimates that 60 percent of Canada's forest industry activity occurs in the boreal region).
- Mining, and oil and gas industrial activities in the boreal region contributed an estimated $14.5 billion to Canada's GDP.
- Hydroelectric generation from dams and reservoirs in the Boreal Shield ecozone contributed an estimated $19.5 billion to Canada's GDP.
- There is an estimated $11.1 billion in air pollution and government subsidy costs associated with forestry and mining sector activities; costs that should, in principle, be deducted from the market GDP value as environmental and social costs of development.

The results of the estimated **total non-market value of boreal ecosystem services** for 2002 include:

Forests

- The *annual* non-market boreal forest ecosystem service values are estimated at $12.4 billion, or $51.24 per hectare per year for 2002; this figure includes an estimated value of $1.85 billion for the annual net carbon sequestered by forests.
- Like a bank account, Canada's boreal forests and peatlands represent a massive storehouse of carbon. An estimated 67 billion tonnes of carbon are stored in the boreal region-the equivalent of 303 years of Canada's total 2002 carbon emissions, or 7.8 years of the world's total carbon emissions in the year 2000. How much is this stored carbon worth to the world? Munich Re, one of the world's largest reinsurance companies, has estimated that the cost to the global insurance industry of continued increases in global carbon emissions to the atmosphere could reach US$304 billion per year by the end of the decade. Using this estimate as a proxy for the value of maintaining carbon storehouses like the boreal region would suggest a value of carbon at US$46 per tonne of carbon (based on total global carbon emissions in the year 2000). Using Munich Re's carbon value estimates would place the value of the current total carbon stored in Canada's boreal "carbon bank account" at $3.7 trillion.

Wetlands and Peatlands

- The annual non-market boreal wetland and peatland ecosystem service values (flood control, water filtering, and biodiversity value) are estimated at $80.4 billion ($934 per hectare of wetland and peatland combined per year), plus $383 million per year for carbon sequestration by peatlands.
- In terms of stock values, 83.2 million hectares of peatland in Canada's boreal region hold an estimated 19.5 billion tonnes of carbon worth an estimated $349 billion (i.e., carbon stock value; $4,195 per hectare).

Nature-Related Recreation[2]

- Approximately 6.1 million Canadians participate in nature-related activities per year in Canada's boreal region, worth an estimated $4.5 billion ($3.8 billion in total nature-related-activity expenditures by participants plus $654.7 million per year in economic value; included in annual forest ecosystem total value).
- Based on input/output modelling, the above boreal region expenditures would have the following economic impact on Canada's economy: $5.7 billion on gross business production, $4.0 billion on GDP, $1.8 billion in government taxes and revenue, and $1.9 billion in personal income generated by 64,500 sustained jobs.

While our account of the boreal region is preliminary, it reveals the importance of measuring the full range of ecological and social values of ecosystems to Canadians. The accounts also begin to show that the increasing pressures on boreal ecosystem integrity from human and industrial development could potentially threaten the future economic well-being of Canadians and global citizens.

Issues for Canadians

The results of our study suggest that Canadians have important issues to contemplate, namely:

- What level of development would be acceptable in order to minimize further fragmentation, loss of intact boreal ecosystems, and the degree of damage to ecosystem function?
- How much of the current intact boreal ecosystems should be protected from future development?
- What are the real economic costs and benefits to Canadians if industrial development of the boreal region is forgone?
- What is the true value of conserving the integrity and full functional capacity of the boreal region's ecosystems for current and future generations of Canadians and global citizens?
- Are other nations willing to pay Canada for preserving the boreal region's ecological goods and services?
- Should Canada adopt a more precautionary and conservative approach to decision making with respect to the boreal region by ensuring ecosystem integrity and optimum ecosystem service capacity are the primary objectives of future land-use planning and development?

In order to answer these questions and make well-informed decisions, all levels of government (federal, provincial, and municipal), working with industry and local communities, need to make a commitment to:

- Develop a system of natural capital accounting, such as the BEWAS, to guide land-use planning, resource management, and economic development policies. This accounting system would include a comprehensive and nationally coordinated inventory of boreal natural capital;
- Incorporate accounts of natural capital and ecological goods and services in national and provincial income accounts to guide economic, fiscal, and monetary policies; and
- Provide full cost accounting of the social and environmental costs associated with natural capital development and total economic valuation of natural capital and ecosystem services.

We consider our estimates of ecosystem service values to be both incomplete and conservative. The primary shortcoming of our BEWAS estimates for 2002 is the lack of data on both natural capital resources and the condition of ecosystem services and functions. For example, there are currently no data available on the actual volume of timber harvested from the boreal region or on the volume of oil and gas extracted.

2 Nature-related recreation is reported as a forest ecosystem value in Table 1.

More importantly, there are currently no data to measure the integrity or health of boreal ecosystems due to a lack of information on ecosystem functions.

Similarly, while it may be possible to account for the area of wetlands in the boreal region, we still know very little about the current state of integrity of their numerous ecological goods and services. Yet, we do have evidence of significant linear disturbance in much of the boreal region due to oil and gas, mining, and forestry development that has resulted in significant terrestrial forest ecosystem fragmentation. The long-term implications, both economic and in terms of ecological sustainability, of this fragmentation are substantial but poorly understood.

Notwithstanding these limitations, our conservative economic value estimates provide an important benchmark for comparing the market values of natural capital extraction with the non-market values of ecosystem services in making trade-offs between further industrial development and ecological wealth preservation.

Recommendations

Ideally, a robust BEWAS will track and report on the changes in the condition of Canada's boreal region over time. A national commitment to more comprehensive natural capital inventories is required in order to complete a BEWAS. Furthermore, the integration and development of the region's true and full economic value in policy and land-use decision-making is critical to protect the existing natural capital and ecosystem functions throughout the boreal region.

Our recommendations identify important roles that federal and provincial governments, local representatives, industry, land-use planners, resource managers, scientists, Aboriginal communities, and conservation groups can play in partnership:

1. Given the absence of a complete inventory of the stocks and consumption of timber, minerals, carbon, wetlands, marine resources, wildlife, and fisheries in the boreal region, we recommend that a comprehensive inventory of the area be completed and made publicly available. National, provincial, and local boreal region accounts should be developed including physical stock and flow accounts (inventory) of natural capital assets and ecosystem services. These accounts should include information on the following: annual average growth rate of timber; fires (in terms of both area and volume lost); insect infestation; carbon sequestration by forests and wetlands; fisheries; and annual water flow rates in rivers and groundwater aquifers. Finally, these accounts should include an account of the state of ecosystem services in order to track or measure changes in ecosystem functionality and their respective service values.
2. We recommend that the specific effects of each type of human disturbance be identified, tracked, and monitored to determine the change in economic value of the boreal region's ecosystem services.
3. We recommend that economic values for ecosystem services be further developed and adopted by all jurisdictions for resource and land-use planning, especially at the municipal and provincial levels where changes in land-use and resource planning are made.
4. Our analysis found that the total non-market value of boreal ecosystem services is 2.5 times greater than the net market value of boreal natural capital extraction. This result indicates that an economic argument exists that supports a significant expansion of the network of protected areas in the boreal region, consistent with the Boreal Forest Conservation Framework's vision for sustaining the integrity of the region. We recommend that a policy be developed to expand the network of protected areas in the boreal region that would serve as an investment in the natural capital of the boreal region for the benefit of current and future generations of Canadians and global citizens.
5. We recommend that in order to ensure the optimum value of ecosystem services is recognized and conserved, resource management and land-use decisions need to account for impacts (i.e., costs and benefits) on ecosystem services and the overall state of the region's natural capital. The Boreal Forest Conservation Framework's vision of conservation-based resource management practices should be implemented in order to minimize costs and maximize local ecological values.

1. INTRODUCTION

Garth Lenz

Canada's boreal region represents one of the world's most important ecological treasures. It is one of the last large areas in the world that still supports a full suite of native species in large, connected ecosystems shaped by powerful natural forces like wind and fire. There is growing recognition of the boreal region's *natural capital*—the resources, living systems, and ecosystem services provided by Earth's biosphere, including the ecological systems that support life—and its role in providing for the well-being of Canadians and life everywhere on the planet.

According to the UN's Millennium Ecosystem Assessment report *Ecosystems and Human Well-being* (2005), *ecosystem services*[3] are the benefits people obtain from ecosystems. These benefits include the following: *provisioning services* such as food, water, timber, and fibre; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual value; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling.[4]

While ecosystem services are fundamental to human well-being, their economic value is not taken into account in national measures of economic progress, such as the gross domestic product (GDP), and in decisions on land-use planning and industrial development. Indeed, the ecological integrity of Canada's boreal region, and thus its services, can diminish while GDP rises, indicating that Canada's financial wealth is increasing without consideration for the cost of losses in natural capital and ecosystem services.

Information on the distribution, status, and economic value of most ecosystem services is poor, particularly for the boreal region. In addition, the depletion of natural capital in the boreal region is not accounted for in Canada's GDP and national income accounts.

This study is an attempt to bring to light a full account of the state and total economic value of Canada's boreal ecosystem services and natural capital assets. Such an account of Canada's natural capital, for an area as vast and important as the boreal region (which covers roughly 58.5 percent of Canada's land mass), is vital to ensure the long-term sustainability, integrity, and prudent stewardship of the boreal region for the well-being of both Canada and the world.

1.1 Canada's Boreal Region

The boreal region (*Boreas* comes from the Greek god of the North Wind) is Canada's largest ecoregion, covering over 58.5 percent of the country, or 584 million hectares (5.8 million square kilometres) from Newfoundland and Labrador to the Yukon.[5] Canada has the second-largest area of northern forests, after Russia.

3 An *ecosystem* can be defined as "a dynamic complex of plants, animals, microbes, and physical environmental features that interact with one another." (from the Millennium Ecosystem Assessment: *Ecosystems and Human Well-being: Opportunities and Challenges for Business and Industry.* Synthesis Report).

4 United Nations, *Millennium Ecosystem Assessment Synthesis Report* (New York: United Nations, 2005), p. 9.

5 Our estimate of the size of the boreal region comes from Canada's National Forest Inventory (CanFI), http://nfi.cfs.nrcan.gc.ca/canfi/data/ecozones-small_e.html. We used the CanFI data because (a) it is currently the most widely acceptable data on the boreal region, and (b) it ensures consistency for the purposes of our accounting study. We are aware that there is a debate about the true size of the boreal region. For example, the Canadian Boreal Initiative (CBI) uses an estimate of 574 million hectares, which is based on a new definition of the boreal region. The new definition results in a moderately larger boreal land mass than the definition developed by Stan Rowe, because it includes portions of Rowe's Great Lakes—St Lawrence region and some of what he had identified as tundra. The CBI figure excludes the southernmost part of the Boreal Shield, known as the Algonquin—Lake Nipissing ecoregion, because the dominant vegetation, which includes species such as sugar maple, is not characteristic of the boreal region. Other ecoregions along the southern fringe of the boreal region also contain some uncharacteristic vegetation, although not to such an extent as the Algonquin—Lake Nipissing ecoregion. The line forming the boreal boundary is best regarded as a gradient. As a result, the boundary may adjust based on future analyses. See J. S. Rowe. *Forest Regions of Canada* (Ottawa: Department of the Environment, Canadian Forestry Service, 1972), Publication No.1300. The issue of discrepancies between boreal region area estimates must ultimately be resolved to ensure consistency in future boreal ecosystem wealth accounting.

Canada's boreal forest is one of the three largest "frontier forests" remaining on the planet.[6] This region includes 90 percent of Canada's remaining large intact forests, and 25 percent of the world's remaining large intact forests.[7] In addition, 35 percent of the world's wetlands are in Canada's boreal region[8]; and 40 percent of Canada's wetlands designated as internationally important are located in its boreal region.[9]

Globally, the boreal region is important because it provides many essential goods and services. It filters millions of litres of water on an average day; stores carbon; produces oxygen; rebuilds soil and restores nutrients; holds back floodwaters; releases needed water into rivers, streams, and oceans; and provides food and shelter for hundreds of species. The boreal forest teems with life, including soil microbes and soil fungi; tiny fragile lichens; small colourful songbirds; and some of the world's largest remaining populations of woodland caribou, wolves, and bears. A recent study determined that up to three billion birds breed in North America's boreal region each year, which only emphasizes its importance to the continent's wildlife.[10]

The boreal region contributes to the economic well-being of all Canadians. It is richly endowed with timber, minerals, and oil and gas that are a significant part of Canada's GDP. A recent estimate of the GDP generated by industrial activity in the boreal region is $64 billion, or 10 percent of Canada's GDP.[11]

In Canada in 2002, over 60 percent of forestry activity by area harvested and over 50 percent of forestry activity by volume harvested are estimated to occur in the boreal region;[12] these activities support over 7,000 forest-related enterprises in the region and provide jobs for 395,000 people in logging and related industries.

Canada's total mining, and oil and gas extraction activities contributed $65.3 billion, or 5.6 percent, to Canada's GDP in 2002.[13] An estimated 80 percent of total mining activity[14] and 37 percent of petroleum and natural gas extraction activity[15] occur in the boreal region. Direct employment for 2002 in mining was 52,300, including quarrying aggregates such as sand and gravel, less than half of 1 percent of national employment.[16]

The industrial footprints of forestry, mining, oil and gas, road building, and agricultural development are growing rapidly, particularly along the southern fringes of Canada's vast boreal region. Since the late 1980s, over $13 billion of new and expanded pulp mills and oriented strand board mills have been constructed to exploit the previously untapped volumes of timber to feed a growing export demand for forest products, largely destined for US markets.[17] Large-scale clear-cutting, and oil and gas exploration and extraction, which have laid down thousands of kilometres of seismic lines, have severely fragmented wildlife habitat and Aboriginal traditional lands used for food gathering, trapping, and hunting.

Overall, the boreal region has only 3 percent of its area converted to other land uses. However, 31 percent of its remaining area has been accessed by industrial develop-

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6 The other two are in Russia and Brazil.

7 Peter Lee. *Boreal Canada: State of the Ecosystem, State of Industry, Emerging Issues and Projections (Report to the National Round Table on the Environment and the Economy)* (Ottawa: National Round Table on the Environment and the Economy, 2004).

8 Ibid., p. 7.

9 Designated by the Ramsar Convention on Wetlands, and retrieved September 2, 2005 from the Ramsar website http://www.ramsar.org.

10 Peter Blancher and Jeffrey Wells. *The Boreal Forest Region: North America's Bird Nursery* (Ottawa: Canadian Boreal Initiative and Boreal Songbird Initiative, 2005), http://www.bsc-eoc.org/borealnurseryrpt.html.

11 N. Urquizo, J. Bastedo, T. Brydges, and H. Shear. *Ecological Assessment of the Boreal Shield Ecozone* (Ottawa: Environment Canada, Indicators and Assessment Office, Environmental Conservation Service, 2000). This source was referenced in Lee, *Boreal Canada: State of the Ecosystem, State of Industry, Emerging Issues and Projections.* We do not have any more recent GDP estimates specific to the boreal region. As a result, we had to estimate these figures based on the single existing estimate from a 2000 study that uses 1991 GDP data.

12 Canadian Boreal Initiative. *The Boreal in the Balance: Securing the Future of Canada's Boreal Region* (Ottawa: Canadian Boreal Initiative, 2005), p. 18. This estimate was made for CBI by Global Forest Watch Canada based on spatial analysis of the area of the boreal forest that was harvested in 2002. On an area basis, the boreal forest harvest area represents 61.2 percent of Canada's total estimated forest land harvested in 2002. However, in terms of volume of timber harvested, the boreal forest harvest represents only 50.3 percent of Canada's 2002 timber harvest. Original harvest area and volume data for Canada is drawn from the National Forest Database Program, http://www.nfdp.ccfm.org/compendium/harvest/summary_e.php.

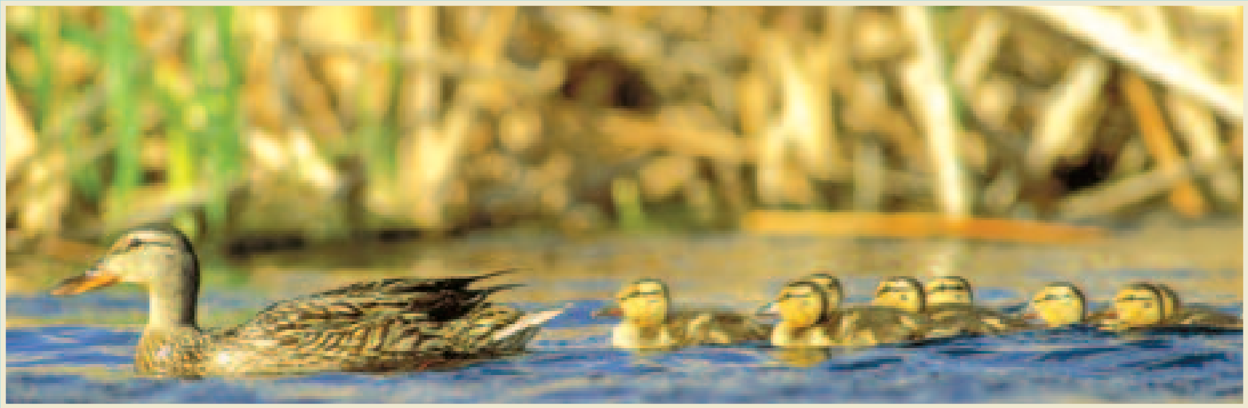
13 Statistics Canada. *Gross Domestic Product at Basic Prices, Primary Industries* (Ottawa: Statistics Canada, 2005), http://www.statcan.ca/english/Pgdb/prim03.htm. Percentages were estimated based on the ratio of mining, and oil and gas extraction GDP contribution to Canada's total GDP in 2002.

14 MiningWatch Canada. *The Boreal Below: Mining Issues and Activities in Canada's Boreal Forest Region* (Ottawa: MiningWatch Canada, 2001), http://www.miningwatch.ca (accessed February 2004).

15 Based on spatial analysis and interpretation of petroleum and natural gas active ("non-abandoned wells") producing wells as of June 2003 by Global Forest Watch Canada, March 30, 2005.

16 Peter Lee. *Boreal Canada: State of the Ecosystem, State of Industry, Emerging Issues and Projections (Report to the National Round Table on the Environment and the Economy)* (Ottawa: National Round Table on the Environment and the Economy, 2004).

17 Retrieved May10, 2005 from Boreal Forest Network website http://www.borealnet.org.



Ducks Unlimited Canada

ment. Approximately 29 percent of Canada's boreal forest has been allocated to forest companies through licences and tenure,[18] while less than 10 percent of the region is strictly protected from development, and there is no consistent application of sustainable resource development management practices.

1.2 Purpose of This Study

The absence of a proper account for the boreal region as a natural capital asset is unfortunate given that this precious network of ecosystems is subject to increasing industrial development pressures. These pressures add to the potential loss and degradation of natural capital based on past human land use and exploitation of resources.

The conversion of ecosystems for other uses, including forestry, mining and energy industries, residential development, roads, and other industrial development, has led to the loss of ecological connectivity and ecosystem services. Resource management decisions and investment decisions are largely influenced by consideration of the monetary costs and benefits associated with the market values of natural capital, which tend to favour forestry, agriculture, and mining activities. Unfortunately, these activities affect the non-market values of ecosystem services. However, because ecosystem services have not been given a market value, rarely have they been accounted for in resource policy decisions.

The primary questions this study set out to answer were the following:

- What is the full range of ecological goods and services that Canada's boreal region provides for the well-being of Canadians and global citizens?
- What are the total economic values (both market and non-market values) of the boreal region's ecological goods and services?
- How can Canada develop a system to account for and report on the state of the natural capital assets and ecological integrity of its boreal region?

This study presents the **Boreal Ecosystem Wealth Accounting System (BEWAS)**, the first beta-model, or framework, of its kind for the long-term development of a natural capital accounting system for Canada's boreal region. The BEWAS considers both the physical state and economic value of the boreal region's natural capital assets. Using physical inventory data along with spatial data (e.g., satellite imagery and ancillary data such as roads, petroleum well sites, populated places), we were able to construct a first, albeit preliminary, account.

We hope that this work ultimately leads to a national commitment by various levels of government along with non-profit organizations and industries working in the boreal region, to the development of a comprehensive boreal ecosystem and natural capital accounting system for Canada. Such an account should ultimately inform Canadians on the ongoing state and sustainability of Canada's boreal region as a natural capital patrimony.

This study represents a step towards such a desired outcome. It establishes a baseline against which genuine progress towards sustainability of the boreal region can be measured and managed. Ultimately, its purpose is to ensure that the integrity of the boreal region is maintained without any regrettable net loss to its wide range of ecological goods and services.

18 Canadian Boreal Initiative. *The Boreal in the Balance,* (Ottawa: Canadian Boreal Initiative, 2005) p. 18.

Garth Lenz

2.

MEASURING THE TOTAL ECONOMIC VALUE OF ECOSYSTEM GOODS AND SERVICES

Garth Lenz

Valuing natural capital, including ecosystem services, in monetary terms poses methodological challenges. Many efforts have been made by some ecological and environmental economists to derive non-market values for ecosystem services.[19]

The conventional economic valuation would attempt to assess the **total economic value (TEV)** of an environmental resource or ecosystem according to use values and non-use values (see Figure 1).[20] Use values include direct use values, market-based values, and ecological function values; non-use values include option values, quasi-option values, vicarious-use values, bequest values, and existence values.

Use values include both direct and indirect use values.[21] **Direct use values (or benefits)** are derived from the direct use of natural resources as materials, energy, or space for input into human activities.[22] These benefits include the market value of forestry, agriculture, and mining activities, which are generally measured as a GDP value (i.e., the total market value of all goods and services produced by the sector in the economy). This valuation approach is used in the BEWAS to reach the market value of the forestry, mining, oil and gas, and hydroelectric sectors that operate in the boreal region. Direct use values also include other market activities such as commercial fishing, guided fishing trips, boat tours, and non-market activities such as recreation or nature-related activities); of these, only the value of nature-related activities is accounted for in the BEWAS.

Some economists have also described **indirect use values (or benefits)** (not shown in Figure 1), which are values that do not change the physical characteristics of the environment and are sometimes referred to as "non-consumptive" (e.g., the amenity value of a landscape).

Ecological function values (or benefits) are provided by the ecosystem services and functions of a natural resource. They describe the indirect ecological value derived from the interconnectedness of species through a variety of food chain and nutrient cycles. Ecological function benefits may include waste assimilation functions and life support functions, such as the provision of clean air, water, and other resources.

Non-use values (or benefits) comprise option values, quasi-option values, vicarious-use values, bequest values, and existence values. **Option values (or benefits)** are derived from the continued existence of environmental elements that may one day provide benefits for those currently living and for future generations.[23] **Quasi-option values (or benefits)** refer to the welfare obtained from the opportunity to get better information by delaying a decision that may result in irreversible environmental damage. **Vicarious-use values (or benefits** are gained by people from the knowledge that others may be enjoying use of a natural environment, for instance, for recreational activities, commercial activities.

19 The most famous example of this kind of analysis is by Robert Costanza, an ecological economist, and his colleagues who derived an estimate of the ecological service values of the earth's various ecosystems at US$33 trillion per year in 1997, more than double the World's GDP at the time. See Robert Costanza, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton, and Marjan van den Belt. "The Value of the World's Ecosystem Services and Natural Capital," *Ecological Economics* 25 (1998): pp. 3-15. Note, this article first appeared in *Nature* 38, no. 15 (1997): pp. 253-259 and was reprinted in *Ecological Economics* as part of a special issue dedicated to the debate on valuing ecosystem services.

20 According to the UN's conventions on environmental and natural capital accounting (SEEA 2003), the benefits of ecological functions are considered in three categories: resource functions, sink functions, and service functions. These benefits are divided into two broad categories: use values and non-use values.

21 United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, and World Bank. *Handbook of National Accounting, Integrated Environmental and Economic Accounting* 2003 (New York: United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, and World Bank, 2003), Section 7.35, p. 251.

22 Ibid., Section 7.36, p. 251.

23 Ibid., Section 7.37, p. 251.

Bequest values (or benefits) are derived from the continued existence of environmental elements because they may one day provide benefits for future generations.[24] In addition to these non-use benefits, an environmental entity may have **existence values (or benefits)**; that is, an entity—such as a rare species or a special ecosystem—may appear to be of no use to humans now or in the future, but it is beneficial to maintain its existence for the simple satisfaction that the community derives from knowing that it exists (for ethical reasons).[25]

For the purposes of accounting for the boreal region's natural capital and ecosystem functions, the UN *Handbook of National Accounting, Integrated Environmental and Economic Accounting* 2003 provides detailed guidelines on how to construct both physical and monetary accounts of natural capital.[26] These guidelines were used, for the most part, in the development of the BEWAS. While the *Handbook* is useful for accounting for natural capital such as forests, wetlands, land, and water, it is less clear on how to practically develop accounts for ecosystem functions. The *Handbook* notes, "A comprehensive measurement of the environmental services provided by ecosystems is conceptually possible but not comprehensively covered by the *Handbook*. Some accounting for the appearance and disappearance of ecosystem features may be possible in a limited form of account."[27] Therefore, this study is pioneering in the conceptual design and practical construction of accounting for ecosystem services, in general, and for Canada's boreal region, specifically.

Garth Lenz

24 Ibid.

25 Ibid.

26 The *Handbook* is the result of a multi-stakeholder and collaborative effort involving the United Nations, the European Commission, the International Monetary Fund, Organisation for Economic Co-operation and Development (OECD), and the World Bank, as well as through the participation of several governments from various nations.

27 United Nations, European Commission, International Monetary Fund , Organization for Economic Co-operation and Development, and the World Bank. 2003. *Handbook of National Accounting: Integrated Environmental and Economic Accounting* 2003, Section 7.43, p. 269 retrieved September 2, 2005 from the United Nations website http://unstats.un.org/unsd/envAccounting/seea.htm. The handbook is also known as SEEA (Integrated Environmental and Economic Accounting). There are a number of different methods for calculating economic rents outlined in the UN SEEA handbook on pp. 276-278.

In terms of offering an approach to valuing natural resources, the *Handbook* provides useful international environmental accounting guidelines for Canada to consider with respect to accounting for the boreal region's natural capital. Natural capital is valued in terms of the market price of extraction of a natural resource asset or the market value of services to the economy as natural resources are used.

These values are conventionally measured in terms of *economic rent*—the value of the capital service flows rendered by a natural resource or simply the between-the-market price that could be earned for using a natural capital asset (e.g., timber, oil, or fish) and the factor costs of production, including an allowance for returns to invested capital.[28]

Economic rent, in the case of a public natural capital asset, is effectively the net return to provincial governments (with some exceptions) as owners of most natural capital assets. Economic rent values can be applied to both the stock (e.g., total stock of standing timber in a forest) and flows (e.g., value of the annual timber harvest) of natural capital use.[29] Economic rent estimations are only applicable where markets exist for natural resources such as timber, oil and gas, minerals, hydroelectric power, and commercial fish production.

For the purposes of the BEWAS, economic rent estimates are not possible given the lack of data necessary to calculate economic rent. Instead, the GDP of each market-valued natural capital asset by sector (e.g., forestry, mining, petroleum) are used as a crude proxy for the market value of natural capital consumed in industrial production.

In the case of market-based natural capital assets, such as timber, oil and gas, and minerals, the valuation in monetary terms is rather straightforward. Markets reveal the price or monetary value of a natural capital asset. For example, a hectare of land could be valued in terms of both the market value of standing timber, and subsoil oil and gas reserves. It is important to note that the market price does not reflect the true cost of extraction and processing of these goods. This is because, in the case of ecosystem services, there are no markets in which their monetary values are revealed.

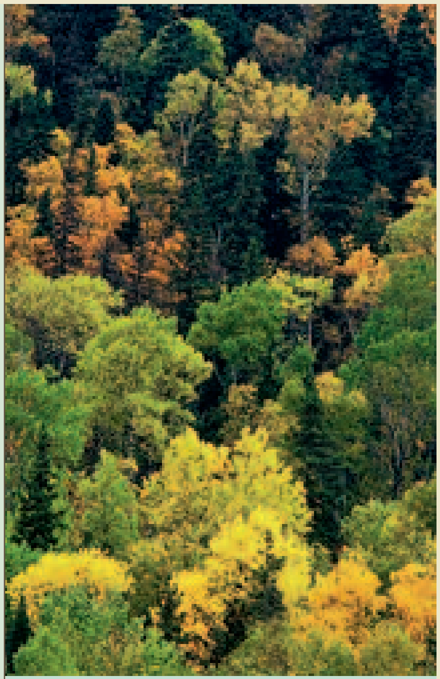
Economists have attempted to estimate monetary values for a variety of non-market ecosystem services using various methodological approaches (e.g., surveying the public's willingness to pay for various ecosystem services or assessing the actual costs of replacing or repairing damaged ecosystem functions).

While useful, these estimates often reveal a wide range of monetary values for similar ecosystem functions (or non-market natural capital), which can lead to confusion in interpreting the most appropriate values to use in making trade-off decisions with market values of natural capital.

For the purposes of this study, the values estimated for the boreal region are primarily based on use benefits—both direct use values and ecological function values. Estimates of non-use values are

28 Ibid., Section 2.136, p. 53.

29 In the case of valuing the stock of a natural capital asset, like timber, the sum total of a discounted value (i.e., net present value, or NPV) of a stream of benefits over the life of the natural capital asset is calculated.



Garth Lenz

The Natural Capital Accounting Challenge

Valuing natural capital, including ecosystem services, in monetary terms poses methodological challenges. Many efforts have been made by some ecological and environmental economists to derive non-market values for ecosystem services.

For the purposes of accounting for the boreal region's natural capital and ecosystem functions, the UN *Handbook of National Accounting, Integrated Environmental and Economic Accounting 2003* provides detailed guidelines on how to construct both physical and monetary accounts of natural capital.

While the *Handbook* is useful for accounting for natural capital such as forests, wetlands, land, and water, it is less clear on how to practically develop accounts for ecosystem functions.

Therefore, this study is pioneering in the conceptual design and practical construction of accounting for ecosystem services, in general, and for Canada's boreal region, specifically.

Figure 1: Total Economic Value of Environmental Resources

Total Economic Value (TEV)

The total economic value of an environmental resource is generally considered to comprise both the use values as well as non-use values generated by that resource.

Direct Use Values

- Commercial forestry
- Commercial mining
- Commercial agriculture
- Commercial fishing, hunting, and trapping
- Recreational fishing and boating
- Nature-related outdoor activities

Ecological Function Values

- Nutrient storage and cycling
- Atmosphere gas and climate regulation
- Waste treatment and assimilation
- Biological control
- Habitat and refugia
- Biodiversity maintenance
- Habitat protection

Non-Use Values

Option Values

The benefit of maintaining the right to use resources without necessarily doing so.

Quasi-Option Values

The welfare obtained from the opportunity to get better information by delaying a decision that may result in irreversible environmental damage.

Vicarious Use Values

Knowing others are enjoying nature's values.

Bequest Values

The maintenance of environmental attributes for the benefit of future generations.

Existence Values

The satisfaction the community derives by knowing that a certain thing (e.g. rare species) still exists.

Source: retrieved September 2, 2005 from National Ocean's website http://www.oceans.gov.au/uses_economic/page_002.jsp

beyond the scope of this study due to the lack of existing research and valuation studies. Thus, our study provides an incomplete accounting of the total economic value of the boreal region's natural wealth.

As the *Handbook* points out, "Actually accounting for each and every environmental asset would require enormous amounts of information, much, if not most, of which will not exist in most countries."[30] Thus, our attempt at even a partial construction of a BEWAS for the boreal region is ambitious and daunting, and its completion is years away.

How then should we proceed in the absence of clear ecosystem service accounting guidelines? There is considerable debate in the academic and professional resource accounting community about the best approach to ecosystem service accounting. Some experts argue that it is best to develop non-market values, while others would like to see more rigorous qualitative measures of ecosystem integrity measurement.[31] Since ecosystem services are not traded in financial markets and thus have no "revealed" market value, proxy values are required for these services.

There are many non-market valuation techniques at our disposal, and our results show the range of value estimates that are possible. More often, the real value of intact ecosystems may only be fully revealed when an ecosystem (e.g., a wetland) has been irreparably degraded or damaged by industrial development. For example, replacement costs or expenditures on built infrastructure intended to replace lost or damaged ecosystem services may act as proxies of their once intact value.

30 United Nations et al., *Handbook of National Accounting: Integrated Environmental and Economic Accounting*, Section 7.40, p. 251.

31 Ecosystem integrity is defined as "the soundness or wholeness of the processes and organisms composing the ecosystem. To maintain ecological integrity one must maintain functioning, self-sustaining ecosystems with characteristics similar to the original ones." See *An Ecosystem Spatial Analysis for Haida Gwaii, Central Coast, and North Coast BC April* 2004 (Victoria, BC: Coast Information Team, 2004), http://citbc.org/c-esa-fin-04may04.pdf. Statistics Canada has considered possible approaches to ecosystem services accounting and suggests that ecosystems are best evaluated in primarily physical terms and not monetary. Their rationale is that, for example,the evaluation of air quality and other ecosystem outcomes is inherently a question of physical measurement. However, physical measurement, as noted above, is complicated by the very complexity of dynamic ecosystems, requiring many indicators of ecosystem functions in order to provide a full picture of ecosystem integrity.

3.

METHODOLOGY: THE BOREAL ECOSYSTEM WEALTH ACCOUNTING SYSTEM FRAMEWORK

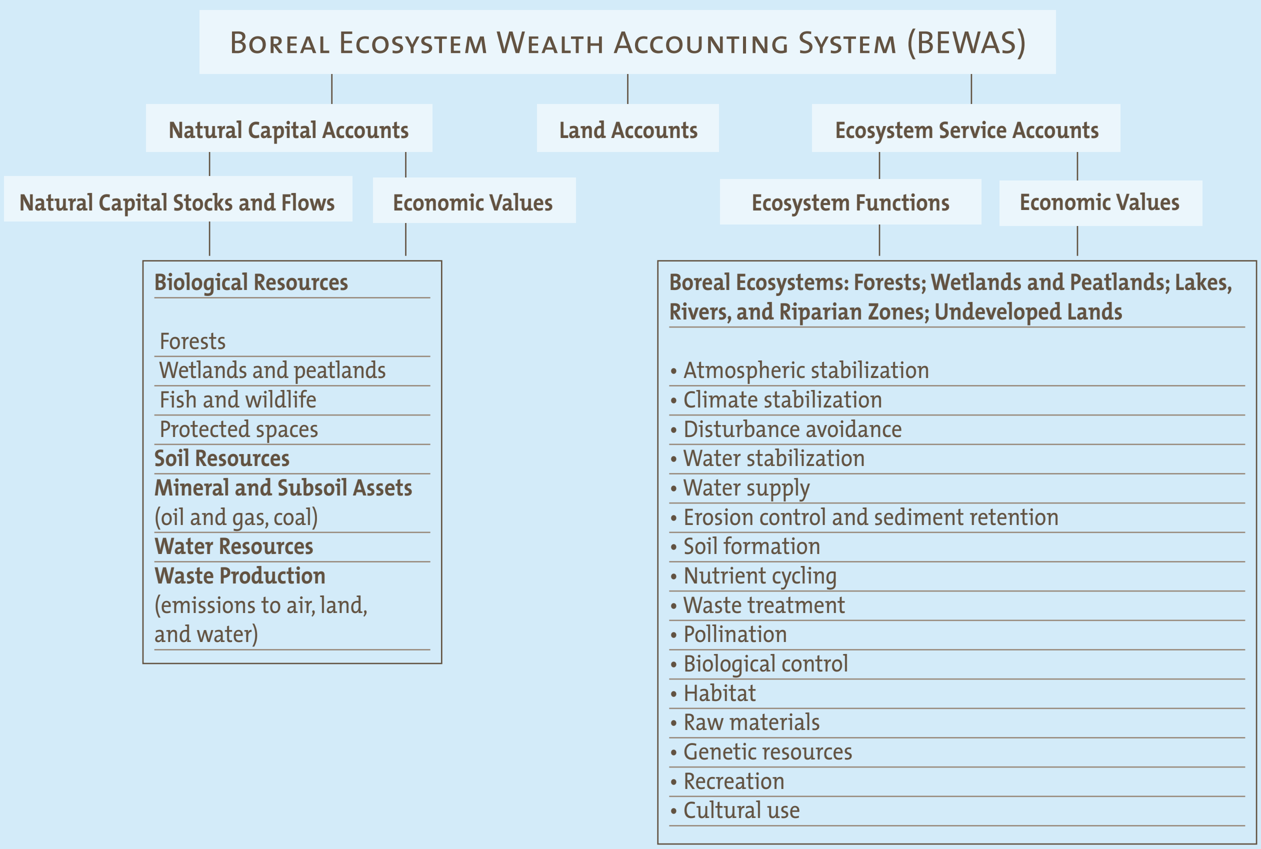
Garth Lenz

3.1 The BEWAS Framework and Methodologies

The primary purpose of this study is to begin to identify, inventory, and measure the full economic value of the many ecological goods and services provided by Canada's boreal region. As a result, we developed the **Boreal Ecosystem Wealth Accounting System (BEWAS)**. Similar to conventional financial accounting systems, which include ledgers (accounts), a balance sheet (assets, liabilities, and owners equity), and an income statement, we propose the BEWAS as an ecosystem wealth accounting and measurement tool to assess the nature, state, and total socio-economic value of the boreal region's natural capital assets and ecosystem services.

The BEWAS framework is designed to track natural resource stocks and flows (of both renewable and non-renewable natural resources), land, ecosystem services (i.e., the state or condition of ecosystem functions), and the total socio-economic value of these natural capital assets—both market and non-market values. Figure 2 shows the proposed BEWAS framework.

Figure 2: Proposed Boreal Ecosystem Wealth Accounting System Framework



The BEWAS framework is consistent with both the UN system of Integrated Environmental and Economic Accounting (SEEA) (see Table 2); the international guidelines for natural capital and environmental accounting; and Statistics Canada's Canadian System of Environmental and Resource Accounts (CSERA), which tracks stocks, flows, and monetary values of Canada's natural resource wealth. The UN SEEA is the current international guide by which nations can begin to account for the sustainability of natural capital assets in the context of economic well-being. The SEEA tackles the overall goal of assessing the sustainability of the economy through different "categories," or modules, of accounts that include: (1) physical and hybrid accounts of natural capital and ecosystem services, which aim to assess ecological sustainability and provide links to the national monetary income accounts (from which GDP is derived); (2) environmental expenditure accounts, which account for defensive expenditures (e.g., environmental protection services, pollution remediation costs, and environmental reclamation expenses); (3) physical and monetary

Table 2: UN System of Integrated Environmental and Economic Accounting: Flow and Stock Accounts with Environmental Assets

			Assets		
		OPENING STOCKS	Economic Assets	Environmental Assets	
	Industries	*Households/ Government*	+		*Rest of the World*
SUPPLY OF PRODUCTS	Domestic Production				Imports of products
	thereof: for environmental protection				thereof: for environmental protection
USE OF PRODUCTS	Economic cost (intermediate consumption, consumption of fixed capital)	Final consumption	Gross capital formation, consumption of fixed capital		Exports of products
	thereof: for environmental protection				thereof: for environmental protection
USE OF NATURAL ASSETS	Environmental cost of industries	Environmental cost of households	Natural capital consumption		
			+		
	OTHER CHANGES OF ASSETS		Other changes of economic assets	Other changes of environmental assets	
			=		
	CLOSING STOCKS		Economic Assets	Environmental Assets	

Source: Peter Bartelmus. "Accounting for Sustainability: Greening the National Accounts," in *Our Fragile World, Forerunner to the Encyclopedia of Life Support Systems*, vol. 2, ed. M. K. Tolba (Oxford: Eolss Publishers, 2001).

asset accounts, which seek to assess the maintenance of natural capital (i.e., environmental sustainability of economic performance); and (4) environmental adjustment accounts, which generate modified economic aggregates, such as a green GDP. According to Peter Bartelmus, "The SEEA reduces its scope and coverage to accounting for environmental sustainability only—at the expense of the social dimension of sustainable development. Its 'ecological approach' thus focuses on ecological sustainability, impaired by pressures on carrying capacities of natural systems; in contrast, the 'capital approach' aims at capturing economic sustainability. The idea is to generate information for assessing both the physical and monetary sides of the sustainability coin."[32]

Statistics Canada is an international leader in natural capital accounting. It developed CSERA,[33] which is based on the SEEA guidelines, to track the state of Canada's natural capital and environmental assets, including: (1) natural capital stocks (e.g., forests and subsoil assets, such as minerals, oil and gas, and coal); (2) urban and rural use of land resources; (3) consumption of materials and energy (e.g., water and energy use); (4) waste production (e.g., greenhouse gas emissions); and (5) environment protection expenditures (e.g., pollution abatement and control expenditures by governments, industry, and households).[34] Some of these accounts for Canada's natural resource wealth show trends from 1961 to the present, and they are used to derive indicators of sustainability, e.g. estimates of energy asset reserve life (i.e., the years of reserves remaining at current production) of Canada's oil and gas resources.

CSERA represents a comprehensive framework for linking the economy and the environment through physical and monetary statistics. It comprises three accounts:

- *Natural resource stock accounts*, which measure quantities of natural resource stocks and the annual changes in these stocks due to natural and human processes. These accounts, which are recorded using both physical and monetary units, form the basis of the estimates of Canada's natural resource wealth that are included in the Canadian National Balance Sheet Accounts.
- *Material and energy flow accounts*, which measure, in physical terms only, the flows of materials and energy—in the form of natural resources and wastes—between the economy and the environment. These accounts are linked directly to the Input-Output Accounts. This linkage allows the calculation of important indicators of resource and waste intensity of economic activity.
- *Environmental protection expenditure accounts*, which identify current and capital expenditures by business, government, and households for the purpose of protecting the environment. These accounts measure both the financial burden associated with environmental protection, plus the contribution of environmental protection to economic activity from a demand-side perspective.

The environmental protection expenditure accounts in particular are simply a decomposition of the existing current and capital accounts for businesses, households, and governments to explicitly show expenditures for environmental protection. Similarly, the natural resource stock accounts, when measured in dollars, are an extension of the current Canadian National Balance Sheet Accounts and show the values of some of the natural resources provided by the environment. The remaining components of the CSERA fall outside the standard framework because they are not measured in value terms and/or because they measure flows that take place outside the boundary of marketplace activity that defines the scope of the national accounts.

CSERA, consistent with the SEEA,[35] divides natural capital into three main components:

1. *Natural resource stocks and flows* (including renewable and non-renewable resources)
2. *Land and associated surface water*
3. *Environmental systems or ecosystems and ecological services*

All three components are considered essential to the long-term sustainability of the economy. Natural resource stocks are the source of raw materials used in the production of manufactured goods (e.g., trees from forests or oil and gas from subsoil deposits). Land is essential for the provision of space in which economic activity can take place (e.g., agricultural soil

32 P. Bartelmus. *Green National Accounting: Measuring Sustainable Economic Growth* (International Workshop on Green Accounting for China, Beijing, November 23-24, 2004).

33 Retrieved September 2, 2005 from Statistics Canada website http://www4.statcan.ca/citygrp/london/venues/fontevraud_progress/canada.htm. The CSERA is designed to fit within the framework of the Canadian System of National Accounts (CSNA).

34 For a complete description of CSERA, see Statistics Canada, *Econnections: Linking the Environment and the Economy* (Ottawa, Statistics Canada, 2001). The report is available through Statistics Canada at http://www.statcan.ca:8096/bsolc/english/bsolc?catno=16-200-X.

35 For a detailed description of the international standards for natural capital and environmental accounting, see United Nations et al., *Handbook of National Accounting: Integrated Environmental and Economic Accounting*.

for food production). Ecosystems are essential for the services that they provide directly and indirectly to the economy, including cleansing of fouled air and water; provision of productive soil; provision of biodiversity; provision of a predictable and relatively stable climate; protection from incident solar radiation; and provision of reliable flows of renewable natural resources.

3.1.1 BEWAS Natural Resource Accounts

In the BEWAS framework (see Figure 2), the natural capital accounts comprise natural capital stocks and flows and their economic values. Although ecosystem services are part of natural capital, in this framework, they are reported separately as ecosystem service accounts. This is because accounting for ecosystem services involves primarily a qualitative assessment of the integrity or functionality of various ecosystem functions rather than a physical inventory of stocks and flows as is the case for natural resources, such as timber. Natural capital is the sum total of renewable and non-renewable resources. Natural capital accounting experts argue that in order for sustainability to be achieved, renewable natural capital stocks cannot be consumed at rates which exceed the natural regeneration rate of these stocks. Moreover, if the natural functioning of the ecosystem is disrupted, degraded, or destroyed by human activities to such a point that the quality of the services they provide declines, then that level and type of economic production is no longer sustainable.[36]

An example of an application of Statistics Canada's natural capital account for Alberta forests, developed by the authors of this study, is shown in Table 3. The timber natural capital account tracks changes (flows) in the total stock of forest land, timber volumes, and the economic value of these forest capital assets over time.

Table 3: Alberta Forest Resource Accounts Model

	Forest Land Area	Timber Volume	Monetary Valuation*
[1] Opening stock Additions: + [2] Natural growth + [3] Land-use additions	(hectares)	(cubic metres)	($)
Reductions: - [4] Harvest - [5] Fire - [6] Insects and disease - [7] Mortality - [8] Loss due to roads, energy, and agricultural development	(hectares)	(cubic metres)	($)
[1+2+3-4-5-6-7-8] = [9] Closing stock	(hectares)	(cubic metres)	($)

Sources: Mark Anielski, *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); Mark Anielski, *Accounting for the Sustainability of Alberta's Forests—The 1995 Timber Resource Account* (unpublished paper, 1996); and Mark Anielski and Sara Wilson. *Alberta GPI Accounts: Forests* (Ottawa: Pembina Institute for Appropriate Development, 2001).

* The economic value of timber capital is based on applying economic rent (economic rent = price less costs of production) estimates by the timber volume.

36 Robert Smith, Claude Simard, and Andrew Sharpe, A Proposed Approach to Environment and Sustainable Development Indicators Based on Capital (Prepared for The National Round Table on the Environment and the Economy's Environment and Sustainable Development Indicators Initiative) (Ottawa: Statistics Canada, January 2001), p. 5.

Both additions (natural growth of trees and land-use additions) and reductions (industrial development and natural disturbances [e.g., fire] that affect forest land and timber volumes) are accounted for. A natural capital account is similar to a bank account. The account begins with an annual opening balance of forest land and timber volume and is adjusted by annual additions of timber capital volume (i.e., growth) and reductions from the timber capital inventory.

The relationship between timber capital "interest" (growth) and "expenditures" (depletions or reductions) defines the sustainability of timber capital; that is, the extent to which we are living "off the interest" of forest capital or depleting our forest capital account at unsustainable levels. Anielski and Wilson developed a Timber Sustainability Index (TSI)—the ratio between total annual growth of the forest timber supply and the annual reductions from both natural and human disturbance—as an indicator of the overall sustainability of timber capital in Alberta.[37]

3.1.2 Boreal Land Accounts

The boreal land accounts describe the physical area by land type and show how much of the land base is allocated to commercial or industrial development, how much is protected from development under protective legislation, and how much remains undesignated. The boreal land included in these accounts are areas designated for industrial land-use planning, areas under protected designation for wilderness conservation, and areas currently occupied or used by the mining and petroleum sector.

Table 4 presents the various categories of land types in the boreal region. Land, as a stock, is fixed in terms of its total physical area. However, changes in the way that land is used can occur (e.g., forest land can be converted to agricultural land, and agricultural land can be converted to urban land).

Table 4: Boreal Lands Accounts Framework

Boreal Land Accounts (by area)
Forests
Wetlands and peatlands
Water bodies: rivers, streams, lakes
Other non-designated boreal land area
TOTAL boreal land area
Boreal land designated for land-use planning (current and future allocation to forestry)
Parks and natural areas under protected designation
Mineral lease land
Undesignated boreal land area (estimated)

Evaluating land from the perspective of cover type (e.g., trees, crops, or buildings) can also serve as a measur e of the use of land. In some cases, the same parcel of land may have multiple uses (e.g., timber production, recreation, and wildlife habitat), but it will have only one cover type (e.g., mixed forest). In the BEWAS, the boreal land accounts track the total area of land by type of land use by ecosystem type.

Land accounts should also distinguish between intact versus developed ecosystems and by land designated for preservation (e.g., parks) or commercial/industrial use (e.g., timber harvesting). This first BEWAS account only accounts for the area of boreal region land under various land-use classifications or designations such as forest and other wooded land, wetlands, peatlands, lakes, and reservoirs.

However, using Geographic Information Systems (GIS) analytic tools developed by Global Forest Watch Canada, estimates of the degree of fragmentation and linear disturbance of the boreal region from industrial

Garth Lenz

37 Mark Anielski and Sara Wilson, *The Alberta GPI Accounts: Forests*, Report #20 (Drayton Valley, AB: Pembina Institute for Appropriate Development, September 2001).

development were made in an attempt to assess the integrity (i.e., intact state) of the boreal forests. Some of these results are shown in Appendix II of this report. Considerably more work would be required to provide an accurate account of the qualitative state of the boreal region's ecosystems.

3.1.3 Boreal Ecosystem Service Accounts

Ecosystem services are produced by interactions within the dynamic complex of plants, animals, microbes, and physical environmental features that make up an ecosystem. These services are also referred to as the benefits

Table 5: Ecosystem Services and Their Functions

Ecosystem Service	Ecosystem Function	Examples of Services
Atmospheric stabilization	Stabilization of atmospheric chemicals	Co_2/o_2 balance; stratospheric ozone; So_2 levels
Climate stabilization	Regulation of global temperature, precipitation, and other climate processes	Greenhouse gas production and absorption; cloud formation
Disturbance avoidance	Integrity of ecosystem responses to environmental fluctuations	Storm protection; flood control; drought recovery; vegetation structure that helps to cope with environmental variability
Water stabilization	Stabilization of hydrological flows	Supply water for agriculture use (irrigation), industrial use, or transportation
Water supply	Storage and retention of water	Water storage by watersheds, reservoirs, and aquifers
Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of soil loss by wind and runoff; storage of silt in lakes, wetlands; drainage
Soil formation	Soil formation process	Weathering of rock; accumulation of organic material
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation; nitrogen/phosphorous, etc.; nutrient cycles
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess nutrients and compounds	Waste treatment; pollution control; detoxification
Pollination	Movement of floral pollinators	Provision of pollinators for plants
Biological control	Regulation of pest populations	Predator control of prey species
Habitat	Habitat for resident and transient populations	Nurseries; habitat for migratory species
Raw materials	Natural resource primary production	Lumber; fuels; fodder; crops; fisheries
Genetic resources	Sources of unique biological materials and products	Medicine; products for materials; science; genes for plant resistance and crop pests; ornamental species
Recreation	Opportunities for recreation	Ecotourism; wildlife viewing; sport fishing; swimming; boating; etc.
Cultural	Opportunities for non-commercial uses	Aesthetic; artistic; education; spiritual; scientific; Aboriginal sites

Sources: Amanda Sauer. *The Values of Conservation Easements* (discussion paper, World Resources Institute, presented to West Hill Foundation for Nature, December 1, 2002); Robert Costanza et al. *The Value of the World's Ecosystem Services and Natural Capital. Nature* 387 (1997): pp. 253-260.

38 United Nations, *Millennium Ecosystem Assessment Synthesis Report* (New York: United Nations, 2005).

that humans obtain from ecosystems. Services include provisioning, regulating, and cultural services that directly affect people. They also include supporting services, which are needed to maintain all other ecosystem services. Some are local services and others are regional or global in nature.[38]

In the BEWAS framework, the ecosystem service accounts comprise the ecosystem services provided by the boreal region based on ecosystem function. Accounting for ecosystem service values (physical, qualitative, or monetary values) represents the most daunting challenge for natural resource and environmental accounting.

Intuitively, we know that these complex ecosystems are critical to human and ecological well-being, even without attempting to measure their values. At best, we can identify some of the observed functions and services of the boreal region, and use rough proxies or indicators to assess the integrity of these functions (i.e., measure outcomes such as clean water). Indicator species (e.g., a species of plant, fish, wildlife, or other biota) can serve as proxies of ecological integrity in either terrestrial or aquatic ecosystems. However, scientific research into species-based indicators of ecological integrity, particularly in terrestrial ecosystems, is in its infancy.[39]

Table 5 provides a detailed list of ecosystem functions and services that could be accounted for in an ecosystem accounting structure such as the BEWAS. It also provides a useful framework for guiding further development of the BEWAS. Unfortunately, many of these ecosystem services are difficult to measure and place a value on.

Table 6 provides a list of the ecosystem functions of the boreal region. We were able to provide either a physical account or economic value estimate for those

Table 6: Boreal Ecosystem Service Accounts Structure and Data

Ecosystem	Ecosystem Service	Ecosystem Service Value Assessed
Forests	* Atmospheric and climate stabilization	Carbon storage and annual carbon sequestration by forests
	Disturbance avoidance	[a]
	* Water stabilization and water supply	Watershed service: municipal water use-cubic metres/year (database incomplete)
	Erosion control and sediment retention	[a]
	Soil formation	[a]
	Nutrient cycling	[a]
	Waste treatment	[a]
	Pollination	[a]
	Biological control	[a]
	Habitat	[a]
	* Raw materials	• Subsistence values for Aboriginal communities and households • Non-timber forest products (mushrooms, berries, and wild rice)
	* Genetic resources	• Biodiversity: value of birds for pest control • Biodiversity: passive value—willingness to pay (WTP) for conservation
	Air quality	[a]
	* Recreation	Economic value to Canadians from recreation-related activities in the boreal region
	* Cultural	Subsistence values for Aboriginal communities and households

39 See *Appendix I* for a discussion on the state of measuring ecological integrity.

Table 6: Boreal Ecosystem Service Accounts Structure and Data

Ecosystem	Ecosystem Service	Ecosystem Service Value Assessed
Wetlands and peatlands	* Atmospheric and climate stabilization	Carbon storage and annual carbon sequestration by wetlands and peatlands
	* Disturbance avoidance	Flood control, water filtering, and biodiversity value
	* Water stabilization and water supply	Included in flood control, water filtering, and biodiversity value
	* Erosion control and sediment retention	Included in flood control, water filtering, and biodiversity value
	Soil formation	[a]
	Nutrient cycling	[a]
	Waste treatment	[a]
	Pollination	[a]
	Biological control	[a]
	Habitat	[a]
	* Raw materials	Part of subsistence values for Aboriginal communities and households
	* Genetic resources	Included in flood control, water filtering, and biodiversity value
	* Recreation	Included in the economic value to Canadians from recreation-related activities in the boreal region
	* Cultural	Part of subsistence values for Aboriginal communities and households
Lakes, rivers, riparian zones	* Atmospheric and climate stabilization	[a]
	Disturbance avoidance	[a]
	Water stabilization and water supply	[a]
	Erosion control and sediment retention	[a]
	Soil formation	[a]
	Nutrient cycling	[a]
	Waste treatment	[a]
	Pollination	[a]
	Biological control	[a]
	Habitat	[a]
	* Raw materials	Included in subsistence values for Aboriginal communities and households
	Genetic resources	[a]
	Air quality	[a]
	* Recreation	Included in the economic value to Canadians from recreation-related activities in the boreal region
	* Cultural	Included in subsistence values for Aboriginal communities and households
Undeveloped lands	* Cultural	Included in the economic value to Canadians from recreation-related activities in the boreal region

a Data not available to assess ecosystem service value.

Source: Boreal Ecosystem Service Accounts based on Nancy Olewiler. *The Value of Natural Capital in Settled Areas of Canada* (Stonewall, MB, and Toronto: Ducks Unlimited Canada and the Nature Conservancy of Canada, 2004).

marked with an asterisk. For example, it was possible to account for the amount of carbon stored and annually sequestered by forests and peatlands in the boreal region and estimate a range of economic values for these ecological goods and services. For some ecological functions, such as pollination and soil formation, data were not available.

Our proposed BEWAS represents an idealized environmental accounting framework. Ideally, all ecosystem functions should be accounted for by measuring their physical and qualitative conditions and their economic value. However, as with natural capital inventories, there is a general lack of information about the state of boreal ecosystem functions. Therefore, it is currently not possible to account for the integrity of boreal ecosystems in accordance with the diversity of their ecological functions.

While the availability of physical or quantitative data was a serious constraint to the construction of a set of boreal ecosystem accounts, we were fortunate to have access to a wealth of spatial, geo-coded information from various sources including satellite imagery (see section 3.2 *Data Limitations*). We were also able to estimate the economic values of some ecosystem functions, goods, and services drawing from a large and growing body of environmental and ecological economics literature.

To account for the effects of human and natural disturbance on the conditions, state, or integrity of ecosystem functions, as well as their economic value, a Pressure-State-Response (PSR) model[40] may provide a useful framework (see Table 7). Using this framework, it is possible to account for the various kinds of human and industrial pressures on ecosystems, as well as changes in the economic values under various ecological conditions. These pressures include industrial development, community development, and other human pressures

Table 7: Ecosystem Service Accounting Structures Model

Ecosystem	Pressure	Condition (*State*)			Economic Values		
		Intact	Modified	Developed	Value assuming all intact	Value under current *modified* ecosystem conditions from industrialization	Value under current *developed* ecosystem conditions from industrialization
Forests							
Wetlands and peatlands							
Aquatic (lakes, rivers, streams, riparian zones)	*(human and natural disturbance)*		*(high, medium, or low conservation utility*)*			*($)*	
Other undeveloped land or ecosystems							

* *Conservation utility* is used by the Coast Information Team in their report *An Ecosystem Spatial Analysis for Haida Gwaii, Central Coast, and North Coast BC April* 2004. The term refers to a broad measure of the irreplaceability of ecosystems in terms of their function, where irreplaceability is defined in two ways: (a) the likelihood that a particular area is needed to achieve an explicit conservation goal; or (b) the extent to which the options for achieving an explicit conservation goal are narrowed if an area is not conserved. For purposes of accounting for the condition or state or productivity of an ecosystem, the concept and measure of conservation utility (ranging from high, medium, and low utility) may be useful within the BEWAS framework.

40 The PSR model has been used by many Organisation for Economic Co-operation and Development (OECD) countries, the World Bank, and other nations for environmental reporting. The PSR is a convenient representation of the linkages among the pressures exerted on the land by human activities (pressures), the change in quality of the resource (state), and the response to these changes as society attempts to release the pressure or to rehabilitate land that has been degraded (response). The interchanges among these human pressures and natural resource states form a continuous feedback mechanism that can be monitored and used for assessment of land quality. See OECD. *OECD Core Set of Indicators for Environmental Performance Reviews. A Synthesis Report by the Group on the State of the Environment* (Paris, France: OECD, 1993), p. 35 and http://www.fao.org/docrep/W4745E/w4745e08.htm.

Northern Images Wayne Sawchuck

on natural systems. They also include natural disturbance pressures (e.g., fire) that affect the state or condition or integrity of an ecosystem. It should be noted that natural disturbance is part of an ecosystem's state of being and can be seen as one of nature's services. For example, wildfires can have a catastrophic impact on a forest ecosystem, yet they are critical to the renewal of an ecosystem and a necessary disturbance for the regeneration of some boreal species; so a natural disturbance may not necessarily be a negative occurrence/pressure.

To assess the pressures on ecosystem functions, spatial analysis using geo-coded data and GIS was useful for estimating some natural capital stocks and flows (e.g., estimates of timber harvesting in the absence of a national boreal harvest inventory), and ecosystem pressures (e.g., estimates of the industrial footprint and ecosystem fragmentation).

While incomplete, such analysis could be developed with more sophisticated satellite imagery and spatial analysis and eventually serve as an early warning system that a potential ecological tipping point (i.e., a sudden bifurcation or sudden ecosystem functional collapse) may be on the horizon due to increasing industrial development pressures.

Such analysis, used in the context of the precautionary principle,[41] could be useful for decision makers who are concerned about avoiding the potential irreversible loss or degradation of ecosystems and their functions.

It is clear that significant challenges remain with respect to measuring both the qualitative state and value of ecosystems in terms of their ecosystem services. Indeed, applying economic value estimates to the total area of existing ecosystems such as forests and wetlands effectively assumes that each respective ecosystem service accounted for is functioning at its optimum level. This would tend to overstate ecosystem service values.

On the same hand, the losses of ecosystem service values due to ecosystem degradation are not being accounted for in the absence of a qualitative assessment of ecosystem integrity. We know from spatial analysis of forest fragmentation due to industrial development, for example, that large and growing sections of the southern boundary of the boreal region are in less than an optimum ecological state of health and functionality. A better estimate of the current value would be measured in terms of the regrettable loss or costs to human and ecological well-being associated with human and industrial

41 *The precautionary principle*, a phrase first used in English circa 1988, is the ethical theory that if the consequences of an action, especially concerning the use of technology, are unknown but are judged by some scientists to have a high risk of being negative from an ethical point of view, then it is better not to carry out the action rather than risk the uncertain, but possibly very negative, consequences. See http://en.wikipedia.org/wiki/Precautionary_principle.

development. However, we feel that the ecosystem values presented in this study are conservative because we have not accounted for the full list of ecosystem functions.

We estimated approximate values for ecosystem services where possible based on the best and most current economic valuation methods. The values have been applied to the respective area of each ecosystem or its approximate component (e.g., the estimated climate regulation benefits, in terms of carbon sequestration, are based on the economic value per tonne of carbon stored by the total forested land in the boreal region). The valuation methodology and sources used to calculate the value of ecosystem functions are outlined in section 4.2.3 *The Economic Values of Boreal Ecosystem Services*. In general, we took the following steps to determine the most appropriate ecosystem service values for the boreal region:

1. We conducted a literature review to find the best available information on the extent of each boreal ecosystem and its attributes.
2. We conducted a literature review to identify ecosystem valuation studies undertaken within the boreal region.
3. If ecosystem valuation studies within the boreal region were not available, we conducted a literature review and contacted experts to assess the most appropriate current studies and, therefore, values available for benefits transfer to the boreal region.
4. We used the following criteria in deciding on an ecosystem service value for benefits transfer:
   a. Where a value from a study on the boreal region was available, we adopted it (e.g., replacement cost of carbon through afforestation; biodiversity conservation).
   b. Where a direct use value could be assessed, we adopted it (e.g., municipal water use).
   c. Where a market proxy value existed, we adopted it (e.g., recreation values).
   d. Where a large range of values was presented in the literature, we adopted results from a meta-analysis (e.g., wetland values).

3.2 Data Limitations

In attempting to construct a preliminary BEWAS, we conducted an exhaustive search of numerous government and other datasets on natural capital related to the boreal region that could be used to "populate" our BEWAS framework with real current and historical data.

It became evident that there is inadequate boreal-specific baseline information on the current state and rate of change of the boreal region's resources, which is critical for monitoring the conditions and overall sustainability of the boreal region. For example, data on current stock and changes in the boreal natural capital assets such as forest inventory, minerals, petroleum resources, water resources, fish and wildlife, and arable agricultural land are not currently available.[42]

42 Credible boreal research requires detailed, up-to-date, boreal-specific data. Unfortunately, the current state of CanFI lacks satisfactory boreal-specific baseline information on the nature and rate of change to the boreal region's resources. Our requests for boreal-specific inventory were ultimately frustrated as we waited months for basic raw data that would give us a single dataset for the area and volume of standing timber in the boreal region. The research process was also hampered by the reality that each province, which maintains control of provincial forest inventories, must approve the release and use of data on a publicly owned natural capital asset. This experience was both frustrating and disappointing given the importance of such knowledge for the effective stewardship and sustainability of boreal ecosystems. Other challenges also persist, including irregular provincial inventories (i.e., province inventories vary because of different methods and years of inventory). Even when we eventually did receive the CanFI boreal-only inventory, several problems were identified with the dataset. Ultimately we chose to use basic boreal ecozone forest land area data available on the CanFI website.

Natasha Moine

Towards a Natural Capital Balance Sheet

The natural capital assets found in the boreal region are vast and play a major role in global cycles (e.g., hydrological flows, carbon sequestration) that support life on Earth.

Canada continues with industrial development in the boreal region without tracking or monitoring the consequences of development for its natural capital. This is akin to a major corporation like Coca Cola or Noranda charting a business course without a complete inventory and balance sheet of its key assets.

Prudence would argue that a full assessment of natural capital assets and the values of ecosystem services should take place prior to further development of the region.

Moreover, flow data such as the volume and rate of timber harvesting, the impacts on forests of other land-use development (e.g., oil and gas development), and the impact of forest fires on boreal forests are not available. Our attempts to develop a boreal carbon account (the amount of carbon stored and sequestered annually) based on Canada's National Forest Inventory (CanFI) were hampered by a lack of sufficient progress on, and utility of, Canada's emerging carbon budgeting model. Most importantly, there is simply no information or measures of the integrity of boreal ecosystems, and thus no capacity for assessing the condition of ecosystem services. In the absence of hard, quantitative inventory data, we faced a daunting challenge in constructing a meaningful set of economic value estimates for the boreal region's natural capital and ecosystem services.

The natural capital assets found in the boreal region are vast and play a major role in global cycles (e.g., hydrological flows, carbon sequestration). Thus, it is hard to fathom that Canada has such limited information on the overall condition of the boreal region.

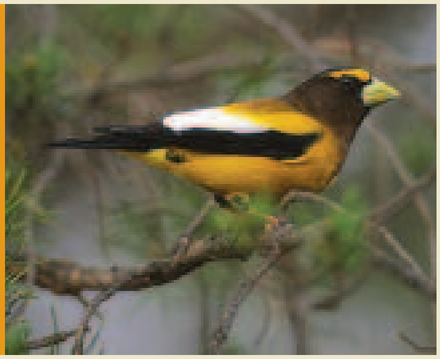
Despite this information deficit, Canada continues with industrial development in the boreal region without tracking or monitoring the consequences. This is akin to a major corporation like Coca Cola or Noranda charting a business course without a complete inventory and balance sheet of its key assets. Despite significant data limitations, we were able to populate parts of the BEWAS with both estimates of the stocks and flows of some key natural capital accounts (proxies for actual inventories) by extracting spatial, geo-coded data on the boreal region. Using these datasets, we were able to estimate economic monetary values for both market and non-market natural capital extraction and ecosystem services.

In the absence of concrete quantitative data for the boreal region, land-use decision-making and development in the region will continue to be poorly informed. Prudence would argue that a full assessment of natural capital assets and the values of ecosystem services should take place prior to further development of the region.

Garth Lenz

4.

RESULTS AND SUMMARY: ECONOMIC VALUES OF CANADA'S BOREAL NATURAL CAPITAL AND ECOSYSTEM SERVICES



Ducks Unlimited Canada

This section summarizes the study's findings on the physical conditions of the boreal region's natural capital assets and ecosystem services. Each account in the Boreal Ecosystem Wealth Accounting System (BEWAS) is further detailed in this section of the study, which describes the findings and provides a brief summary of data sources and accounting methodologies.

4.1 Boreal Land Accounts

Table 8 presents the area of boreal land accounts categorized by land-use category and land base by designation or allocation (under land-use planning or currently in use by industry). The table shows that the most significant land account is forests (forest and wooded land), which cover 328,634,000 hectares, or 56.3 percent of total boreal land area. Peatlands are next in size, and cover 83,200,000 hectares, or 14.2 percent of total boreal land area. Lakes cover 59,227,000 hectares, or 10.1 percent of total boreal land area.[43] The balance of the boreal land account includes 2,836,800 hectares of wetlands (0.5 percent of total boreal land area) and other undesignated, or unidentified, boreal land that makes up the final 106,078,200 hectares (or 13.8 percent of total boreal land area).[44] In addition, there are areas of water bodies: rivers, lakes, and reservoirs, and wildlife habitat.

Table 8: Boreal Land Accounts

Boreal Land Accounts	Detailed Land Accounts	Area (ha)
Land Category		
Forests	* Forest land only * Wooded land only * Total forests	241,985,000 86,649,000 328,634,000
Wetlands and peatlands	* Wetlands * Peatlands	2,836,800 83,200,000
Water bodies: rivers, streams, lakes	* Lakes * Reservoirs	59,227,000 4,103,000
Other non-designated boreal land area		106,078,200
TOTAL boreal land area		584,079,000
Area of Boreal Under Allocation or Designation		
Boreal land designated for land-use planning (current and future allocation to forestry)		169,382,000
Parks and natural areas under protected designation		53,971,000
Mineral lease land (* Industrial footprint area of mining facilities, well sites, pipelines, and other industrial use		46,225,000
Undesignated boreal land area (estimated)		314,470,000

Sources: Canadian Forest Service, Canadian National Forestry Inventory (available at http://nfi.cfs.nrcan.gc.ca/canfi/data/classification-large_e.html), and Global Forest Watch Canada.

43 Figures for forest land only, wooded land area, and the total boreal region area are from the most current CanFI. Estimates of wetlands, peatlands, lakes, and reservoirs are estimated by Global Forest Watch Canada; these estimates were not available from CanFI.

44 Since we are using two different data sources, CanFI and Global Forest Watch Canada, we cannot assure that all figures are accurate or additive, though we have reconciled all figures to the total boreal region area estimate of 584,079,000 hectares reported by the CanFI database.

4.2 Boreal Natural Capital and Ecosystem Service Accounts

Table 10 provides an overall summary of the results of the BEWAS, showing stock, flow, and monetary economic value estimates for 2002.[45] For the most part, the reporting period is only a single point in time depending on the year of the data that was available (either a standard benchmark year like 2002 or the next best data year).[46]

Monetary economic value estimates used a single year estimate of the current market or non-market value. In the case of market values, GDP estimates for forestry and mining/petroleum industry activities were estimated for the boreal region for 2002.

Table 9 shows the distribution of land within the boreal region by ecozone.

Table 9: Boreal Land Account by ecozone

Boreal Region Ecozones	Area (hectares)
Taiga Plains	63,722,000
Taiga Shield	135,431,000
Boreal Shield	199,642,000
Boreal Plains	74,412,000
Taiga Cordillera	26,366,000
Boreal Cordillera	47,772,000
Hudson Plains	36,734,000
TOTAL	584,079,000

Source: Canadian Forest Service, retrieved September 2 at the CFS website http://nfi.cfs.nrcan.gc.ca/canfi/data/ecozones-small_e.html.

Table 10: Boreal Ecosystem Wealth Natural Capital Accounts, 2002

Boreal Ecosystem Wealth Natural Capital Accounts	Stock and Flow Data	Monetary Economic Values and Regrettable Costs (2002$)[a]
Forests	**Stocks:** * **14.7 billion cubic metres** in the volume of standing timber in the boreal ecozones, all age-classes * **242 million hectares** in total forest land area in the boreal ecozones (or 41.4% of total boreal land area) **Flows:** * **95.2 million cubic metres** is the annual timber harvested from the boreal forest in 2002 (est.) * **2.46 million hectares** is the average annual area of boreal forest burned from 1980 to 1997 * **236.2 million cubic metres** of timber burned per annum due to forest fires from 1980 to 1997 * **92.9 million hectares** of boreal forest land has been fragmented due to linear disturbance from industrial development and industrial footprint (roads, seismic lines, pipelines, well sites, etc.) **Other indicators:** * **169.4 million hectares** of boreal forest (or 29.0% of total boreal land base) designated under land-use planning for current or future forestry development * **0.65%** is the ratio of timber harvested in 2002 to the total timber volume * **19.6%** of the boreal forest land area has been fragmented due to linear disturbance from industrial development	**Market values:** * $14.9 billion in estimated market value of forestry-related GDP in the boreal region (est. 2002) * $61.41/hectare, forestry-GDP per hectare of total area of forest land area in the boreal region (est. 2002) **Costs:** * $150 million in estimated cost of carbon emissions from forest industry activity in the boreal region (deduction against forestry-related GDP)

45 The year 2002 was chosen as the benchmark year since much of the data we were able to gather came from this reference year. In some cases, where noted, data were older and in others more current; however, for purposes of a standard accounting period we chose 2002. All economic value estimates are shown in 2002 dollars; some older value estimates were converted to 2002 dollar estimates using Canada's GDP chained implicit price index.

46 In the case of market values for forestry, mining, and oil and gas activities, GDP figures were available for 2003 and 2004; however, as noted for reasons of comparability with other value estimates, we chose 2002 as the benchmark year for relative comparison of both market and non-market values.

Table 10: Boreal Ecosystem Wealth Natural Capital Accounts, 2002

Boreal Ecosystem Wealth Natural Capital Accounts	Stock and Flow Data	Monetary Economic Values and Regrettable Costs (2002$)[a]
Forests (cont'd)	**Ecosystem services:** * **47.5 billion tonnes** of carbon storage * **103.6 million tonnes** of annual carbon sequestration by forest biomass and soil * **368 million cubic metres** of water per year; watershed service: municipal water use (cubic metres/year [database incomplete]) * Subsistence value for Aboriginal communities and households (51,166 households in boreal region) * Non-timber forest products (60% of commercial value for mushrooms, berries, and wild rice) * Biodiversity: $21.48 per hectare for value of pest control by birds * Biodiversity: passive value—willingness to pay (WTP) for conservation: $16.81/household for 50% of boreal households * **6.1 million** Canadians participated in nature-related activities (all ecosystems)	**Non-market values:** * $849.2 billion for value (replacement cost: afforestation) of the total carbon stored in forests * $1.9 billion for annual net carbon sequestration (excludes peatlands) * $18 million for watershed service (i.e., municipal water use) * $575 million in subsistence value for Aboriginal peoples * $79 million in non-timber forest products * $5.4 billion in value for pest control services by birds * $12 million for passive conservation value * $4.5 billion for nature-related activities
Wetlands and peatlands	**Stocks:** * **2.8 million hectares** of wetlands in the boreal region (or 0.5% of total boreal land area) * **83.2 million hectares** of peatlands in the boreal region (or 14.2% of total boreal land area) * **19.5 billion tonnes** of carbon stored in peatlands (only) **Flows:** * **21.4 million tonnes** of carbon sequestered annually by boreal peatlands (2002 est.) **Ecosystem services:** * **19.5 billion tonnes** of carbon storage in peatlands * **21.4 million tonnes** of annual carbon sequestration by peatlands * **Flood control** * **Water filtering** * **Biodiversity values**	**Non-market values:** * $341.6 billion in estimated replacement cost value of carbon stored in peatlands * $383 million in estimated annual replacement cost value of peatlands sequestering carbon * $3.4 billion for flood control, water filtering, and biodiversity value by non-peatland wetlands * $77.0 billion for flood control and water filtering by peatlands only
Fish and wildlife	**Stocks (boreal endangered species):** * **23,819 hectares** of habitat for **whooping cranes**, and **5.5%** of this area impacted by habitat fragmentation from industrial development * **514,078 hectares** of habitat for **woodland caribou (southern mountains)**, and **57.7%** of this area impacted by habitat fragmentation from industrial development * **22,614,635 hectares** of habitat for **woodland caribou (boreal)**, and **12.7%** of this area impacted by habitat fragmentation from industrial development * **9,644,986 hectares** of habitat for **woodland bison (boreal)**, and **39.6%** of this area impacted by habitat fragmentation from industrial development * **20,132,602 hectares** of habitat for **wolverine (western region)**, and **7.7%** of this area impacted by habitat fragmentation from industrial development * **5,600,927 hectares** of habitat for **wolverine (eastern region)**, and **5.2%** of this area impacted by habitat fragmentation from industrial development	*Note: The market value of wildlife related to commercial trapping or fishing industries was not estimated due to the lack of statistics or analysis specific to the boreal region.*

Table 10: Boreal Ecosystem Wealth Natural Capital Accounts, 2002

Boreal Ecosystem Wealth Natural Capital Accounts	Stock and Flow Data	Monetary Economic Values and Regrettable Costs (2002$)[a]
Protected spaces	**Stocks:** * **53.75 million hectares** of boreal region (or 9.2% of total boreal land area) is under protected designation	*not analyzed*[b]
Soil resources (agricultural soil by capability)	*not analyzed*	*not analyzed*[c]
Minerals and subsoil assets	**Stocks:** * **46.25 million hectares** is the estimated area of mining, and oil and gas industrial footprint (or 7.9% of total boreal land area)	**Market values:** * $14.5 billion in GDP from mining, and oil and gas industrial activities in the boreal region (est. 2002) * $24.87/hectare, GDP value for mining, and oil and gas industrial activities per hectare (based on total boreal land area; est. 2002) **Costs:** * $541 million in federal government expenditures as estimated subsidies to oil and gas sector in the boreal region * $474 million in government expenditures as estimated subsidies to mining sector in the boreal region
Water resources	**Stocks:** * **59.2 million hectares of lakes** and **4.1 million hectares of reservoirs** covering the total boreal land area[d] **Flows:** * **368 million cubic metres** of water used by municipalities in the boreal region from forest watersheds (2002 est.)	**Market values:** * $19.5 billion in GDP for hydroelectric generation from dams and reservoirs in the Boreal Shield ecozone (est. 2002)
Waste production (emissions to air, land, and water)	**Flows:** * **4,911 tonnes** of total carcinogens and toxic substances by industry * **1,411,086 tonnes** of total emissions to air of SO_2, NO_2, $PM_{2.5}$, and VOC (tonnes) in 2002 • 180,824 tonnes of NO_2 • 1,129,108 tonnes of SO_2 • 22,406 tonnes of $PM_{2.5}$ • 78, 668 tonnes of VOC[e] * **14 million tonnes** of carbon emissions due to fossil fuel use by forest products sector	**Costs:** * $9.9 billion in estimated air pollution costs to human health[f]

Note: Figures are shown in millions in this table while summary Table 1 shows figures in both billions and millions. Market values are shown in blue; non-market values are shown in green; and environmental/societal costs are shown in red.

Data Sources: Please refer to the various valuation sections in the report for full source references.

a A GDP chained, implicit price index was used throughout report to standardize to 2002 dollars.

b The value of protected spaces (e.g. parks and designated wilderness) were not calculated for this study, however, some of these values may be included in the value of nature to Canadians estimates.

Table 10: Boreal Ecosystem Wealth Natural Capital Accounts, 2002

Boreal Ecosystem Wealth *Natural Capital* Accounts	Stock and Flow Data	Monetary Economic Values and Regrettable Costs (2002$)[a]
TOTAL market values (forestry, mining, oil and gas activities, and hydroelectric generation)		**$48.8 billion**
Less cost of pollution and subsidies: * Air pollution costs * Government subsidies to mining sector * Federal government subsidies to oil and gas sector * Forest sector carbon emission costs		- $9.9 billion - $474.2 million - $540.8 million - $150.2 million
NET market value of boreal natural capital extraction		**$37.8 billion**
TOTAL non-market value of boreal ecosystem services		$93.2 billion
RATIO of non-market to market values		**2.5**

c The state and economic value of the boreal region's soil resources were not analyzed in the absence of data on soil assets.

d Spatial area estimates of rivers and streams are not available, nor are groundwater inventory (stock) and flow data. Total water volume estimates are not available.

e From the National Pollution Release Inventory (emissions to air, only).

f Based on European Union air pollution cost estimates for SO_2, NO_x, $PM_{2.5}$, and VOC for 2002.

Non-market values were estimated for some boreal ecosystem services using various approaches. As a result, market and non-market values for the boreal region can be compared.

In conjunction with the market value estimates for forestry and mining/petroleum industry operations, the environmental costs of air pollution from industry operating in the boreal region, the costs of carbon emissions due to fossil fuel use by the forest products sector, and the costs of government expenditures (measured as government "subsidies") that support mining, and oil and gas activities operating in the boreal region were estimated and deducted.

The combined GDP market value of the forestry, mining, oil and gas, and hydroelectric generation sectors in the boreal region totalled an estimated $48.9 billion for 2002 (before environmental depreciation costs and government subsidies), or roughly 4.2 percent of Canada's GDP in 2002 ($1,158 billion).[47] Since we lack detailed information regarding current boreal-related GDP figures that could confirm the total percentage of GDP from Canada's boreal region, we derived a GDP value based on estimates for the forestry, mining, oil and gas, and hydroelectric generation sectors. It is certain that our GDP estimate understates the full GDP value of all industrial activity in the boreal region.

47 Our GDP estimate differs from an earlier 1991 estimate of $64 billion in GDP from market-based industrial activity in the boreal region or 10 percent of Canada's total GDP. The $64 billion estimate in GDP from the boreal region comes originally from N. Urquizo et al. *Ecological Assessment*. If the 1991 GDP estimate were indexed or inflated to 2002 dollars (assuming the same relative size of GDP from hydroelectricity), then this would equate to a GDP of $75.5 billion in 2002, $10.3 billion higher than our estimate. Moreover, if we apply the 1991 estimate that 10 percent of Canada's GDP comes from the boreal region to Canada's 2002 GDP, then this would equate to a boreal-related GDP estimate of $115.8 billion.

Using available data, we deducted some of the government expenditures to the mining, and oil and gas sector, as well as estimates of the cost of fossil fuel use by the forest products sector and the health costs associated with air pollutants released by industry in the boreal region. It is certain that we have not accounted for the full costs of regrettable environmental depreciation from industrial activity and the full costs of total government subsidies or direct expenditures that benefit industry in forestry, oil and gas, and other sectors. However, this study does offer a preliminary full cost account of the net economic value of market-based natural capital use, where regrettable environmental or ecological depreciation costs are deducted from the gross value of industrial development (as measured by GDP).

The net market value of boreal natural capital extraction is estimated at $37.8 billion on an annualized basis for 2002; air pollution costs from industrial emissions, government subsidies to the mining, and oil and gas sectors, and the estimated costs of carbon emissions due to fossil fuel use by the forest products sector are included as deductions in this figure. Meanwhile, the total non-market value of boreal ecosystem services is estimated at $93.2 billion for 2002. Our analysis reveals that when we compare the market and non-market values for 2002, **the total non-market value of boreal ecosystem services is 2.5 times greater than the net market value of boreal natural capital extraction.**

The following sections of this study provide a more detailed description of each of the BEWAS natural capital and ecosystem service function accounts we examined, including a brief description of the methods we used to estimate stocks, flows, indicators, and economic values.

Garth Lenz

Table 11: Market Values of Boreal Natural Capital and Associated Environmental and Societal Costs

Natural Capital Resource	Stock (total)	Flow (annual extraction)	Market Value GDP (2002$ billions)	Market Value per Hectare (2002$/hectare)
Market Values				
Forestry	14.7 billion cubic metres (volume) 242 million hectares (area)	95.2 million cubic metres harvested 593,811 hectares harvested	$14.9 billion	$61.41
Mining, oil and gas		46.3 million hectares (industrial footprint)	$14.5 billion	$24.87
Hydroelectric generation			$19.5 billion	
Subtotal Market Values			**$48.9 billion**	$83.63[a]
Costs				
Air pollution health costs (industrial emissions)		180,824 tonnes NO_2; 1,129,108 tonnes SO_2; 22,406 tonnes $PM_{2.5}$; 78,668 tonnes VOCs	- $9.9 billion	
Government support expenditures (mining)			- $474 million	
Federal government support expenditures (oil and gas)			- $541 million	
Forest sector carbon emissions costs		14 million tonnes released due to fossil fuel use	- $150 million	
Subtotal Costs			**- $11.1 billion**	
NET MARKET VALUES			**$37.8 billion**	

Source: Boreal Ecosystem Wealth Accounts; see various section of report for details.

a The estimated market values per hectare for forestry and mining are not additive since they reflect a different land base of operations.

4.2.1 Market Values of Boreal Natural Capital

Table 11 summarizes the estimates of the total market values associated with the extraction and development of the boreal region's natural capital. Forestry, mining, oil and gas, and hydroelectric generation are the largest industries operating in the boreal region and have a combined economic value (based on GDP estimates) of $48.9 billion based in 2002.[48] When the cost of government support expenditures for the mining, and oil and gas sectors, the cost to human health of industrial air pollution, and the cost of fossil fuel use by the forest products sector are taken into account, the net market value of the development of the boreal region's natural capital is estimated at $37.8 billion.

Details of each of the market-value estimates and the estimated environmental and societal costs associated with industrial development are provided in the following sections.

48 While GDP figures for 2003 and 2004 were available for some of the sectors, we chose 2002 as our benchmark or standardized year of account to facilitate comparison of other market and non-market values.

Garth Lenz

4.2.1.1 Boreal Forest Timber Volume and Market Value

The total stock of forest land in the boreal region is 241,985,000 hectares according to Canada's National Forest Inventory (CanFI) for 2001.[49] The stock of standing timber volume across the boreal region is an estimated 14.7 billion cubic metres.[50] In the absence of accurate timber harvest figures for the boreal region, it was estimated that the annual timber harvest in 2002 was roughly 95.2 million cubic metres (0.65 percent of total timber volume), or an estimated 593,811 hectares of forest land area harvested (0.25 percent of total boreal forest area). This estimate was derived from spatial analysis conducted by Global Forest Watch Canada by taking the spatial estimates of the area of forest harvested in the boreal ecozones times the reported timber volume harvested by province (see Table 12).

49 Canada's National Forest Inventory. *CanFI Data Summaries: Area Classification by Terrestrial Ecozone and Province/Territory*, 2001, retrieved September 2, 2005 from the CFS website http://nfi.cfs.nrcan.gc.ca/canfi/data/classification-large_e.html.

50 In the absence of available national forestry inventory data on timber harvest from the boreal region, Global Forest Watch Canada roughly estimated the percentage of Canada's Boreal/Taiga ecozones that are harvested by volume and by area. The harvest estimates are based on the following: British Columbia—2% of the volume and 5% of the area are harvested in the Boreal/Taiga ecozones. The assumptions are: (a) The vast majority of the harvest is from the Montane Cordillera and Pacific Maritime Ecozones; (b) the more northerly Boreal Cordillera, Boreal Plains, and Taiga Plains ecozones show minor harvest areas, based on viewing satellite images; (c) the Boreal/Taiga ecozones are furthest from market and production facilities and therefore have received minor harvesting in comparison to the other ecozones; (d) areas of Boreal/Taiga ecozones that are harvested produce less wood per equivalent area than other ecozones in BC. Alberta—100% of the volume and 100% of the area are harvested in the Boreal/Taiga ecozones. The assumption is that very minor amounts of harvested wood come from the more southerly Montane Cordillera and Prairies ecozones. Saskatchewan—100% of the volume and 100% of the area are harvested in the Boreal/Taiga ecozones. The assumption is that no harvested wood comes form the more northerly Taiga Shield ecozone and a negligible amount comes from the Prairies ecozone. Manitoba—100% of the volume and 100% of the area are harvested in the Boreal/Taiga ecozones. The vast majority of the logging occurs in the Boreal Shield and Boreal Plains ecozones (and none from the other Boreal/Taiga ecozones, namely, Taiga Shield and Hudson Plains) and a negligible amount comes from the Prairies ecozone. Ontario—95% of the volume and 95% of the area are harvested in the Boreal/Taiga ecozones. Quebec—90% of the volume and 90% of the area are harvested in the Boreal/Taiga ecozones. New Brunswick—0% of the volume and 0% of the area are harvested in the Boreal/Taiga ecozones. There are no Boreal/Taiga ecozones in this jurisdiction. Nova Scotia—0% of the volume and 0% of the area are harvested in the Boreal/Taiga ecozones. There are no Boreal/Taiga ecozones in this jurisdiction. PEI—0% of the volume and 0% of the area are harvested in the Boreal/Taiga ecozones. There are no Boreal/Taiga ecozones in this jurisdiction. Yukon—100% of the volume and 100% of the area is harvested in the Boreal/Taiga ecozones. The assumption is that the only productive forest is within the Boreal/Taiga ecozone, as opposed to the more northerly Southern Arctic and more southerly Pacific Maritime ecozones.

Table 12: Timber Harvest Volume and Area by Province for Canada's Boreal/Taiga Ecozones, 2002[a]

Province	Total Harvest: Roundwood Volume[b] (thousands of cubic metres)	Percentage in Boreal/Taiga Ecozones[c]	Total Roundwood Volume in Boreal/Taiga Ecozones (thousands of cubic metres)	Total Harvest: Area (hectares)[d]	Percentage in Boreal/Taiga Ecozones[e]	Total Harvest: Area in Boreal/Taiga Ecozones (hectares)
British Columbia	73,638	2	1,473	189,277	5	9,464
Alberta	24,683	100	24,683	68,430	100	68,430
Saskatchewan	4,308	100	4,308	25,070	100	25,070
Manitoba	2,050	100	2,050	15,042	100	15,042
Ontario	26,191	95	24,881	184,643	95	175,411
Quebec	39,587	90	35,628	309,195	90	278,276
New Brunswick	10,107	0	0	105,834	0	0
Nova Scotia	6,038	0	0	49,959	0	0
Newfoundland	2,139	100	2,139	22,027	100	22,027
Prince Edward Island	408	0	0	490	0	0
Yukon Territory	7	100	7	42	100	42
Northwest Territories	3	0	0	50	100	50
CANADA	189,159	50	95,170	969,569	61	593,811

a Also see National Forest Database Program, retrieved September 2, 2005 from the CCFM website http://www.nfdp.ccfm.org/compendium/highlights_e.php and http://www.nfdp.ccfm.org/compendium/harvest/summary_e.php.

b National Forestry Database Program, retrieved September 2, 2005 from the CCFM website http://www.nfdp.ccfm.org/compendium/data/2004_10/graphs/5i-l_e.php.

c Estimated by Global Forest Watch Canada (Edmonton) in a special run and analysis using satellite imagery and their GIS system.

d National Forestry Database Program, retrieved September 2, 2005 from the CCFM website http://www.nfdp.ccfm.org/compendium/data/2004_10/tables/com62e.htm.

e Estimated by Global Forest Watch Canada (Edmonton) in a special run and analysis using satellite imagery and their GIS system.

The estimated market value of timber harvesting activities in the boreal region can be measured in terms of share of Canada's forestry GDP, value of shipments, and other market values that come from the boreal region. The total GDP market value for the forestry sector in Canada in 2002 was $29.5 billion, based on Statistics Canada data.[51] We estimate that the boreal region's contribution to Canada's forestry GDP figures is 50.3 percent, based on the percent of timber volume harvest from the boreal region (as a percent of total Canadian harvest volumes). On this basis, we estimate that the boreal region's contribution to Canada's forestry GDP in 2002 was $14.9 billion. The value per hectare of total boreal forest land area is estimated at $61.41 per hectare (based on the ratio of forestry GDP per total boreal forest land area: 241,985,000 hectares).

51 National Forestry Database Program, retrieved September 2, 2005 from the CCFM website http://nfdp.ccfm.org/compendium/data/2004_10/tables/tab82_m_e.php.

Along with the lack of data on timber harvest volumes or area of harvest within the boreal region, the BEWAS account for forests is incomplete because it does not account for natural disturbance depletions (e.g., fire, insects, disease) or the volumes of timber depleted due to industrial development. Moreover, it is missing information on the annual growth rate of the boreal forest's timber.

4.2.1.2 Mining, and Oil and Gas Sector Market Value in the Boreal Region

Minerals and energy (oil, gas, and coal) reserves are a significant form of marketable natural capital in the boreal region. We have included the value of these so-called subsoil assets in the BEWAS consistent with international natural resource accounting conventions.[52] However, there are some who might disagree on whether these subsoil assets should be considered part of the boreal ecosystem and the BEWAS.[53] *The Handbook of National Accounting, Integrated Environmental and Economic Accounting* 2003 states that "subsoil (mineral and energy) resources are inanimate and affect other environmental assets only indirectly in so far as activities associated with mineral extraction disturb the natural environment."[54] We adopted this *Handbook* convention. We attempted to account for the level of stock of these non-renewable subsoil resources in physical terms, the economic life of reserves (i.e., the ratio of total reserves to the current depletion rate as a proxy for sustainability), and the resource rent value using the concept of economic resource rent valuation methods (similar to timber resources).

On a physical scale, most of the Western Canada Sedimentary Basin—which contains 11.4 billion barrels of crude oil reserves,[55] 59.8 trillion cubic feet (Tcf) of natural gas, and the vast 300 billion barrels of potentially recoverable reserves from Alberta's oil sands—are in the boreal region.[56] Coal reserves are estimated at 6,294 million tonnes. An indicator of the economic life of these reserves is the reserves-to-production ratio, which is the number of years a reserve would last at the current rate of production; for natural gas it is 10 years, for crude oil (excluding the oil sands) it is 9 years, and for coal it is 84 years.

The boreal region is relatively rich in mineral resources. According to Global Forest Watch Canada, the primary metal deposits in the boreal region include: lead-zinc (Yukon), gold (Yukon, BC, NWT, Manitoba, Ontario, Quebec, Newfoundland and Labrador), coal (Alberta), copper-zinc (Manitoba, Ontario, Quebec), uranium (Saskatchewan), nickel (Manitoba), platinum group (Ontario), asbestos (Quebec), iron ore (Quebec, Newfoundland and Labrador). The Boreal Shield ecozone alone produces about 75 percent of the total Canadian production of iron ore, copper, nickel, gold, and silver. The Boreal Shield ecozone in northern Saskatchewan is the largest producer of uranium in the world, accounting for 42 percent of the world's uranium production.[57]

The total contribution of the mining, and oil and gas industries to Canada's GDP in 2002 was $32.6 billion, and in 2004 was $33.6 billion.[58] An estimated 80 percent of Canada's mining activity[59] and 37 percent of

52 See the United Nations et al., *Handbook*, pp. 314-322.

53 Ecological economist Tom Green (in an email of May 16, 2005, to Mark Anielski) argues that because mineral and energy resources are subsurface resources, they should not be considered outside the BEWAS. He notes that such flows do not depend on the state/health/integrity of the boreal region. The boreal region could be made into a dead zone, and the oil and gas sector would still extract the non-renewable resource. Including such values, especially given their size, confuses the signal provided by the BEWAS. If non-renewables are included, Green notes, then increased protection will show a drop in non-renewable receipts but an increase in ecosystem services, blurring the trade-off. The BEWAS should focus on the boreal region as a living ecosystem. While we acknowledge Green's concerns, we have adopted the international conventions of environmental accounting outlined by the United Nations et al. *Handbook*.

54 United Nations et al., *Handbook*, p. 314.

55 The estimated 11.4 billion barrels of crude oil consist of 3.3 billion barrels of conventional crude oil, 6.7 billion of oil sands, and 1.4 billion barrels of frontier oil.

56 Lee, *Boreal Canada: State of the Ecosystem, State of Industry, Emerging Issues and Projections*, pp. 29-30.

57 Personal communication with Peter Lee at Global Forest Watch Canada, March 30, 2005.

58 Statistics Canada, retrieved September 2, 2005 from the Statistic Canada website http://www40.statcan.ca/l01/cst01/prim03.htm.

59 Canadian Boreal Initiative. *The Boreal in the Balance*, p. 15. According to GFWC (personal communication with Peter Lee March 30, 2005), 80 communities in the Boreal Shield ecozone supply 75 percent of Canada's iron, nickel, copper, gold, and silver. But, while mines provide employment and purchase goods and services in communities where they are located, the operations are strongly tied to commodity prices in a cyclical market. Populations in mining communities fluctuate dramatically. For example, between 1981 and 1991, Flin Flon, Manitoba, lost 26% of its population; Schefferville, Quebec, lost 85%; and Uranium City, Saskatchewan, lost almost its entire population (which dropped from 2,500 to less than 100). Also according to GFWC, in the boreal region there are approximately 7,000 abandoned mines (Quebec = 800; Ontario = 3,000; Manitoba = 30-100; Alberta = 2,000; Yukon = 120; NWT = 37), 80 operating mines, 42 closed and suspended mines, 66 acid-generating abandoned mines, and 25 projects that are in advanced exploration stages or are under development.

petroleum (oil and gas) activities occurred within the boreal region in 2002.[60] Therefore, we estimated that the GDP value for the mining, and oil and gas industries in the boreal region has a market value of $14.5 billion per year (2002$),[61] or $24.87 per hectare based on the total boreal land area.[62]

4.2.1.3 Hydroelectric Generation: Market Value in the Boreal Region

A recent study estimates the GDP value for hydroelectric generation in the Boreal Shield ecozone for the year 1991 at $16.5 billion.[63] Given that there are no current estimates of GDP related to hydroelectric generation, we used the $16.5 billion estimate for 1991 and indexed the figure to 2002 dollars, which equals $19.5 billion.[64]

4.2.2 Costs of Industrial Development in the Boreal

The GDP-based market value of industrial activities, such as forestry, mining, and oil and gas, does not include many of the costs of development to society. The following costs are examples of the costs to society in terms of government support to for-profit industries and costs associated with the by-products or pollution resulting from industrial activities. The costs we have included are not comprehensive across sectors, nor are they full estimates of the environmental costs.

4.2.2.1 Government Support Expenditures for the Mining Sector

One example of the internal costs that are not accounted for in GDP reporting is government support expenditures. In Canada, government expenditures in support of Canada's mining industry have been estimated at $580 million per year (2000/2001; 2000$).[65] This estimate includes the spending by British Columbia, Ontario, Quebec, and the Yukon Territory governments, as well as federal government expenditures. In effect, government expenditures, which directly benefit a given sector, are generally defined as direct support payments or subsidies. In the case of the mining sector, such expenditures contribute directly to the financial bottom line and viability of the sector and must therefore be counted as such in a full cost accounting framework. When these expenditures are not accounted for (i.e., deducted from the GDP for the mining sector), an upward bias results in the market value of the sector. Thus, our account recognizes estimated government expenditures as subsidies and deducts them from the GDP estimate for the boreal region. Given the assumption that an estimated 80 percent of total Canadian mining activity/ GDP takes place in the boreal region, government expenditures that support the industry are an estimated $474 million (80 percent of total; 2002$).

60 GFWC estimated the percentage of the boreal region occupied by petroleum sector activity; namely it measured activity in terms of the industrial footprint of non-abandoned (i.e., most likely to be actively producing wells) well sites and pipelines. In 2003, there were 280,947 non-abandoned (active) wells in Canada with a total of 461,627 total wells ever developed between 1901 and June 2003). In the Boreal/Taiga ecozones, there are 102,950 non-abandoned (active) wells with a total of 182,558 wells ever developed between 1901 and June 2003. Therefore, the Boreal/Taiga ecozones comprise 37% of all non-abandoned wells in Canada as of June 2003. The source for well sites data is the petroleum and natural gas well sites national dataset obtained from IHS Energy, Calgary, Alberta (2003).

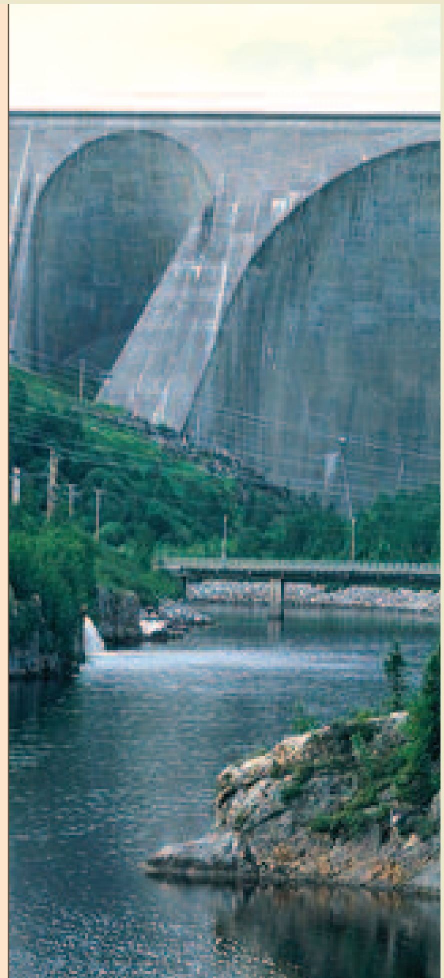
61 Calculated based on an estimated 80% of total Canadian mining activity/GDP in the boreal ecozones, covering the total boreal ecozone land mass.

62 584,079,000 hectares; data was retrieved September 2, 2005 from the CFS website see http://nfi.cfs.nrcan.gc.ca/canfi/data/classification-large_e.html.

63 Lee, *Boreal Canada: State of the Ecosystem, State of Industry, Emerging Issues and Projections.* Data on hydroelectric generation is only available for the Boreal Shield ecozone. Note that there is also hydroelectric generation in the Boreal Plain ecozone (e.g., Grand Rapids, Manitoba, and Tobin Lake, Saskatchewan).

64 A GDP chained, implicit price index was used throughout this study to standardize to 2002 dollars.

65 M. Winfield, C. Coumans, J. Kuyek, and A. Taylor. *Looking Beneath the Surface: An Assessment of Public Support for the Metal Mining Industry in Canada.* (Ottawa: The Pembina Institute for Appropriate Development and MiningWatch Canada, 2002); (2000$).



Garth Lenz

Costing Industrial Development

The GDP based market value of industrial activities, such as forestry, mining and oil and gas, does not include many of the costs of development to society.

For example, there is an estimated $11.1 billion in air pollution and government subsidy costs associated with forestry, oil and gas, and mining sector activities; costs that should, in principle, be deducted from the market GDP value as environmental and social costs of development.

4.2.2.2 Federal Government Support Expenditures for the Oil and Gas Sector

The Government of Canada provided a total of $8.3 billion (2000$) in expenditures to the oil and gas industry between 1996 and 2002, inclusive. During this period, expenditure on oil sands alone was an estimated $1.2 billion (2000$).[66] In 2002 alone, the federal government spent $1.5 billion (2000$) in subsidies to the oil and gas industry. A reported 36.6 percent of petroleum and natural gas wells[67] in Canada are located in the boreal region. Therefore, based on the total federal government support expenditures to the oil and gas sector in 2002, expenditures to industry in the boreal region are estimated at $541 million (36.6 percent of total; 2002$).

4.2.2.3 Carcinogens and Toxic Substance Releases by Industrial Sources in the Boreal Region

Environment Canada's National Pollutant Release Inventory (NPRI) reports on industrial pollutant releases and transfers within Canada. Using the 2002 NPRI database and spatial analysis, we were able to extract data for the boreal region. Figure 3 shows a map of all the industrial sources of pollutants to air, land, and water in the boreal region.[68] The number of NPRI release sites in Canada reported in 2002 was 24,491, of which 5,209 were located in the Boreal and Taiga ecozones.[69]

Figure 3: National Pollutant Release Inventory Sites in the Boreal Region, 2002

Source: Spatial map developed by Global Forest Watch Canada based on NPRI geo-coded database.

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66 A. Taylor, M. Bramley, and M. Winfield. *Government Spending on Canada's Oil and Gas Industry: Undermining Canada's Kyoto Commitment.* (Drayton Valley, AB: Pembina Institute for Appropriate Development, 2005); includes tax, program, and direct expenditures.

67 Non-abandoned.

68 The source of this data is Environment Canada. *National Pollution Release Inventory* (NPRI) 2002, retrieved September 2, 2005 from Environment Canada's website http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm, with updates to the Location Table supplied by Environment Canada, NPRI Office, Prairie & Northern Region, March 14, 2005.

69 Boreal data were extracted using spatial analysis of the NPRI 2002.

Garth Lenz

To determine which substances to consider in our account of released carcinogens and toxics, we relied on the definitions and datasets identified by the North American Commission for Environmental Cooperation.[70] It is important to note that there is overlap between these two release categories; therefore, our account of released carcinogens and toxics is not additive.

The total release of carcinogenic substances in the boreal region was approximately 3,080 tonnes as reported by the NPRI in 2002. The total release of toxic substances in the boreal region, as listed by the Canadian Environmental Protection Act (CEPA), was approximately 3,442 tonnes in 2002. The total release of toxic substances listed by CEPA that were not classified as carcinogens was 1,831 tonnes, including the substance mercury (3,045 kilograms, or 3.045 tonnes). Therefore, the total release of carcinogens and toxics in the region was an estimated 4,911 tonnes in 2002 (see Table 13).

The health costs and ecosystem-related costs were not estimated due to the lack of information on the direct effects of each substance and their associated costs (i.e., illness treatment costs). However, health costs associated with air pollution were estimated (see section 4.2.2.4 *Health Costs Associated with Air Pollutant Releases*).

Table 13: 2002 NPRI Industrial Air Pollutant Releases Categorized as Carcinogens and Toxics in the Boreal

2002 NPRI Pollutant Releases **-Boreal Region Carcinogens and Toxic Substance

Substance Category	Total Releases (tonnes)
Carcinogens	3,080
Toxics	3,442
Overlap	1,611
Toxics not reported as carcinogens (includes mercury releases: 3,045 kg)	1,831
TOTAL	4,911 *

Source: Environment Canada. *National Pollution Release Inventory*. 2002. http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm, with updates to the Location Table supplied by Environment Canada, NPRI Office, Prairie & Northern Region, March 14, 2005.

Note: *The total represents the total releases minus the overlap of the two substance categories (carcinogens and toxins).

** There are 24,491 records in the NPRI 2002 database. Within these, there are 239 records with unidentified locations. Locations were manually identified for 207 of these 239 records, leaving 32 records with unidentified locations. It is also important to note that there are a number of "vagrant" records, which means that their locations are incorrect (e.g., in the middle of the Great Lakes, cities/towns that are hundreds of kilometres from their proper locations).

70 Reference and data retrieved September 2, 2005 from the Taking Stock Query's website http://www.takingstockquery.org/down2001/chemcats_en.html and http://www.takingstockquery.org/down2001/datasets_en.html.

4.2.2.4 Health Costs Associated with Air Pollutant Releases

Based on our analysis of the 2002 NPRI, 1.4 million tonnes of air pollutants were released to the air by industrial facilities located in the boreal region (see Table 14).[71] Using estimates of the marginal external health costs of air pollution in rural Europe, which are reported by the European Commission, the health costs associated with the release of pollutants to the air in the boreal region is an estimated $9.9 billion per year (2002$).[72] Although the cost transferred is from a model based on the effects for rural Europe, the estimates of the health impacts for the emissions were typically up to 1,000 kilometres from the industrial site of emission. Therefore, the costs are suitable for the boreal region, given that most facility locations are in the southern boreal region and that the proximity of large population concentrations in the region and to the south of them is also typically within such a radius.

Table 14: 2002 NPRI Industrial Air Pollutant Releases in the Boreal Region

Total 2002 NPRI Air Pollutant Releases-Boreal Region

Substance	Total Releases (tonnes)	External Costs (millions, 2000$)	Cost/Substance ($/tonne)
NO_2	180,824	1,478.18	8,174.70
SO_2	1,129,108	7,455.09	6,602.64
$PM_{2.5}$	22,406	493.13	22,008.80
VOC	78,668	259.71	3,301.32
Total	1,411,006	9,686.11	
Total (2002$)		9,897.28	

Source: Environment Canada. National Pollution Release Inventory. Data retrieved September 2, 2005 from Environment Canada's website 2002. http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm, with updates to the Location Table supplied by Environment Canada, NPRI Office, Prairie & Northern Region, March 14, 2005.

Note: Cost is an average of the estimated marginal human health costs of air pollution in rural areas from 15 European countries. There are 24,491 records in the NPRI 2002 database. Within these, there are 239 records with unidentified locations. Locations were manually identified for 207 of these 239 records, leaving 32 records with unidentified locations. It is also important to note that there are a number of "vagrant" records, which means that their locations are incorrect (e.g., in the middle of the Great Lakes, cities/towns that are hundreds of kilometres from their proper locations).

4.2.2.5 Cost of Pollution from the Mining Sector

According to a 2004 study, primary mineral production creates 7.2 percent of national greenhouse gas emissions, 40 percent of national sulphur dioxide emissions, and more than 95 percent of national solid waste generation (650 million tonnes per year, at least 20 percent of which is toxic).[73] Further analysis is needed to compile comprehensive data for mining sector pollution costs, and therefore no cost estimates have been included in this study.

4.2.2.6 Cost of Fossil Fuel Use by the Forest Products Sector

According to Apps and colleagues, approximately 14 million tonnes of carbon is released each year due to fossil fuel use by the forest products sector (90 percent from the pulp and paper sector).[74] Carbon emissions due to fossil fuel use by the forest sector are not included in the Forest Carbon Budget because of International Panel on Climate Change (IPCC) guidelines. However, from a full cost accounting perspective, the cost of carbon released during forest product

71 Boreal data were extracted using spatial analysis of the NPRI 2002. They include 180,824 tonnes of NO_2; 1,129,108 tonnes of SO_2; 22,406 tonnes of $PM_{2.5}$; and 78,668 tonnes of VOC.

72 Mike Holland and Paul Watkiss. *Estimates of the Marginal External Health Costs of Air Pollution in Europe: BeTa Version E1.02a*. Created for the European Commission DG Environment by netcen, http://europa.eu.int/comm/environment/enveco/air/betaec02a.pdf. Results reflect the impact of emissions up to a range of, typically, 1000 kilometres from the site of emission. Modelling work undertaken in the ExternE Project has suggested that this is sufficient to capture 95% of the damages associated with emissions. The original method for calculating the estimates that have been adapted for this study were based on the ExternE methodology (European Commission, 1998). This follows the "impact pathway approach," tracing emissions through dispersion and environmental chemistry, to exposure of sensitive receptors, health impacts (calculated using exposure-response functions), and economic valuation using the willingness to pay (WTP) approach. The results for the core analysis presented in this database have been updated to follow some changes to functions, etc. since 1998, and EC DG Environment's preferred approach to economic valuation of mortality, based on a starting point estimate of the value of statistical life of $1 million.

73 Lee, *Boreal Canada: State of the Ecosystem, State of Industry, Emerging Issues and Projections*, p. 33.

74 M. J. Apps, W. A. Kurz, S. J. Beukema, and J. S. Bhatti. "Carbon Budget of the Canadian Forest Product Sector," *Environmental Science and Policy* 2 (1999): pp. 25-41.

Table 15: Boreal Ecosystem Service Value Accounts

Ecosystem	Ecosystem Function	Ecosystem Service Value Assessed	Annual Non-Market Flow Value Estimates (millions, 2002$)
Forests	Atmospheric and climate stabilization	Annual net carbon sequestration (excludes peatlands); carbon storage (i.e., stock value) is an estimated $849.2 billion	$1,852
	Water stabilization and water supply	Watershed service: municipal water use (cubic metres/year [database incomplete])	$18
	Raw materials	* Subsistence value for Aboriginal communities and households * Non-timber forest products (mushrooms, berries, and wild rice)	$575 $79
	Genetic resources	* Biodiversity: value of pest control by birds * Biodiversity: passive value—willingness to pay (WTP) for conservation	$5,401 $12
	Recreation	Economic value to Canadians from recreation-related activities	$4,484
	Cultural	Included in subsistence values for Aboriginal communities and households	*
Wetlands and peatlands	Atmospheric and climate stabilization (peatlands)	Annual carbon sequestration; carbon storage (i.e., stock value) is an estimated $349.1 billion	$383
	Disturbance avoidance (peatlands)	Flood control and water filtering	$76,998
	Disturbance avoidance (non-peatland wetlands)	Flood control, water filtering, and biodiversity value	$3,372
	Water stabilization and water supply		**
	Erosion control and sediment retention		**
	Raw materials	Included in subsistence values for Aboriginal communities and households	*
	Genetic resources	Included in flood control, water filtering, and biodiversity value	**
	Recreation	Included in the economic value to Canadians from recreation-related activities	***
	Cultural	Part of subsistence values for Aboriginal communities and households	*
Lakes, rivers, riparian zones	Raw materials	Included in subsistence values for Aboriginal communities and households	*
	Recreation	Included in the economic value to Canadians from recreation-related activities	***
	Cultural	Included in subsistence values for Aboriginal communities and households	*
Undeveloped lands	Cultural	Included in the economic value to Canadians from recreation-related activities	*
TOTAL Non-Market Value of Boreal Ecosystem Services (flow values only)			**$93,174 million; $159.52/hectare/year**

Note: * included in subsistence values for Aboriginal households of $575.1 million; ** included in flood control, water filtering, and biodiversity value; *** included in the forest ecosystem, recreation ecosystem function economic value estimate.

processing (i.e., related to energy use) should be deducted from the forestry GDP. The costs of carbon released from fossil fuel use by other industrial sectors should also be accounted for. Based on the assumption that 60 percent of Canada's forestry GDP is from the boreal region, the estimated cost of carbon released due to fossil fuel use is $150 million per year (2002$).[75]

4.2.3 The Economic Values of Boreal Ecosystem Services

Table 15 (previous page) provides a summary of the economic values we estimated for the boreal region's ecosystem services.

These estimated values reflect the current economic value of conserving boreal ecosystems in an integral, or intact, state. The total estimated non-market value of boreal ecosystem services is estimated at $93.2 billion for the year 2002, or $159.52 per hectare. The bottom line of our analysis reveals that when we compare the market and non-market values for 2002, the total non-market value of boreal ecosystem services is 2.5 times greater than the net market value of boreal natural capital extraction. The type of valuation and the sources for these values are discussed in the following sections of this study.

4.2.3.1 Total Boreal Forest Ecosystem Service Values

The total forest ecosystem service values for Canada's boreal region are estimated as follows: $849.2 billion for carbon stored, plus $12.4 billion per year in total for all other values ($3509.31 per hectare for carbon storage and $51.24 per hectare per year for all other values; in 2002$; see Table 16), including the value of nature-related activities ($4.5 billion per year) outlined below in the section 4.2.3.6 *The Value of Nature-Based Recreation in Canada's Boreal Region*. The details of each type of boreal forest ecological good and service is described in greater detail in the following sections.

4.2.3.1.1 *Boreal Forest Ecosystem Area and Carbon Estimates*

Canada's National Forest Inventory (CanFI) for 2001 reports that the total stock of forest land in the boreal region is 241,985,000 hectares (includes Boreal and Taiga ecozones). The forest area by ecozone is reported in Table 17. The carbon content stored in forest biomass and soil has been estimated based on the carbon estimates reported by Kurz and Apps' Carbon Budget Model of Canada's Forests.[76]

Garth Lenz

75 This assumes that 60% of forest GDP occurs in the boreal region. Therefore, 60% of the carbon released is valued using the replacement cost of carbon by afforestation ($17.50 per tonne) from S. N. Kulshreshtha, S. Lac, M. Johnston, and C. Kinar, *Carbon Sequestration in Protected Areas of Canada: An Economic Valuation*. (Saskatoon, SK: University of Saskatchewan, Department of Agricultural Economics, 2000).

76 W. A. Kurz and M. J. Apps. "A 70-Year Retrospective Analysis of Carbon Fluxes in the Canadian Forest Sector," *Ecological Applications* 92, no. 2 (1999): pp. 526-541.

Table 16: Summary of Canada's Boreal Forest Ecosystem Service Values (Current Estimated Values of Conserving Natural Capital in Canada's Boreal Region)

Type of Good or Service	Total Forest Land Area (hectares)	Total Value (billions, 2002$)	Value per Hectare (2002$)
Forest carbon storage value-stock value (excluding peatlands)	241,985,000	$333.5 (carbon trading); $849.2 (replacement cost); $2,659 (insurance sector damage costs)	$1,500 $3,227 $10,989
Forest carbon sequestration value-annual flow value (excluding peatlands)	241,985,000	$1.85/year	$7.03/year
Forest watershed value (municipal)		$0.0184/year	
Forest non-timber forest products commercial value (mushrooms, berries, and wild rice)		$0.079/year	
Forest birds-pest control service		$5.4	$21.84
Forest: Aboriginal subsistence value		$0.26 to $0.58/year	$5,000 to $11,000/ household/year (2000$)
Passive values: biodiversity conservation		$0.012/year	$16.81/household/year (50% of boreal household WTP)
Nature-related activities (all ecosystems)	241,985,000	$4.5/year	$18.53/year[b]
TOTAL		$849.2 (carbon storage) plus $12.4/year (all other values)	$3,509.31 (carbon storage) plus $51.24/year (all other values)

a A GDP chained, implicit price index was used throughout report to standardize to 2002 dollars.

b See section 4.2.3.6 *The Value of Nature-Based Recreation in Canada's Boreal Region*; nature-related activities value per hectare per year is calculated using the total boreal forest land base.

Table 17: Canada's Boreal Forest Area and Carbon Storage Estimates by Ecozone

Ecozone	Ecoclimatic Province	Area[a] (millions of hectares)	Carbon Content Estimates[b] (millions of tonnes of carbon)		
			Biomass	Soil	Ecosystem
Taiga Plains	Subarctic	27.9	491	6,781	7,272
Taiga Shield	Subarctic	36.7	646	8,922	9,568
Boreal Shield	Boreal east	119.8	2,292	16,942	19,234
Boreal Plains	Boreal west	36.1	1,146	4,955	6,101
Taiga Cordillera	Subarctic	1.1	19	262	281
Boreal Cordillera	Cordilleran	14.5	1,189	2,903	4,092
Hudson Plains	Boreal east	5.9	113	832	945
Total Boreal ecozones		242.0	5,897	41,596	47,493

a Canadian Forest Service. Canadian Forest Inventory (CanFI 2001), http://nfi.cfs.nrcan.gc.ca/canfi/data/classification-large_e.html.

b Forest ecosystem carbon storage estimates calculated using carbon storage estimates by ecozone for 1990-1994, from Kurz and Apps (1999) Carbon Budget Model of Canada's Forests, as reported by the Canadian Council of Forest Ministers. Criteria and Indicators of Sustainable Forest Management in Canada: National Status 2000 (Ottawa: Natural Resources Canada—Canadian Forest Service, 2000), Criterion 4, http://www.ccfm.org/pi/4_e.html; total forest carbon storage was converted to carbon storage per hectare by ecoclimatic province and then applied to CanFI 2001 forest area data by ecozone.

The total carbon stored per hectare from their model is reported by the Canadian Council of Forest Ministers report: *Criteria and Indicators of Sustainable Forest Management in Canada: National Status* 2000,[77] which was used to calculate the carbon content estimates. As a result, the total carbon stored in boreal forests is an estimated 47.5 billion tonnes (see Table 17).

4.2.3.1.2 *The Value of Climate Regulation: Carbon Storage*

Trees help regulate climate by trapping moisture and cooling Earth's surface. For example, computer simulations estimate that 100 million mature trees in US cities could save as much as US$2 billion per year in heating and cooling energy costs.[78] Information on urban forests and urban trees for the boreal region is not available; therefore, no value for local urban climate regulation has been estimated.

On a global level, forest vegetation and soils capture and store atmospheric carbon dioxide; therefore, they play a significant role in the global carbon cycle and have the potential to affect climate change. For example, in the United States, the Forest Service has estimated that forest carbon sequestration services yield benefits of US$65 per ton, or a total of US$3.4 billion annually for all US forests.[79] Forests absorb carbon dioxide (CO_2) from the atmosphere, convert it to carbohydrates (mainly carbon), and store it in roots, leaves, branches, and trunks. This process is called *photosynthesis*, the principal natural mechanism for removing CO_2 from the atmosphere. Trees release carbon when they become diseased, as they decay, or when they are killed by fire. However, even when they burn, trees release carbon slowly. Only a small portion is released immediately. Most of the carbon goes to the forest floor and into the soil, where it decomposes over a much longer period of time. The whole process of carbon uptake, release to the atmosphere, carbon flow to soil and biomass components is called the *carbon cycle*.

In valuing carbon, it is important to distinguish between the carbon stored within the biomass and soil of existing forest ecosystems and the annual carbon sequestered as a forest grows. In the case of carbon storage, much of the value of carbon is lost if the forest is burned or logged, depending on subsequent land use and the type of forest products (i.e., the lifetime of the product). Carbon sequestration refers solely to the annual net fixation of carbon as a forest grows.

The value of carbon (C) can be estimated by several different methods. First, a significant number of studies base the value of carbon on the cost of climate change to society, namely the damage costs of climate change.[80] A recent review by Clarkson suggests a consensus value of US$34 per tonne of carbon (Cdn$40.95/tC).[81] Tol et al. also reviewed studies reporting an upper cost estimate of marginal damage valued at US$50 per tonne of carbon (Cdn$60.22/tC).[82] As a result, the UN Convention on Biological Diversity suggests using a range of US$34 to US$50 per tonne of carbon (Cdn$40.95 to Cdn$60.22/tC).[83] The risk of future damages due to predicted climate change has also been estimated by the global insurance sector. Munich Re, a global reinsurer, has estimated that the cost of climate change will be $304.2 billion per year by the end of this decade (approximately Cdn$55.42/tC).[84]

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77 Canadian Council of Forest Ministers. *Criteria and Indicators of Sustainable Forest Management in Canada: National Status* 2000 (Ottawa: Natural Resources Canada, Canadian Forest Service, 2000), Criterion 4, http://www.ccfm.org/pi/4_e.htmlhttp://www.ccfm.org/ci/pdf/ns2k/ci_4_e.pdf.

78 J. F. Dwyer, E. G. McPherson, H. W. Schroeder, and R. A. Rowntree. "Assessing the Benefits and Costs of the Urban Forest," *Journal of Arboriculture* 18 (1992): pp. 227-234.

79 B. Dunkiel and S. Sugarman. *Complaint for Declaratory, Mandatory, and Injunctive Relief. United States District Court for the District of Vermont. Burlington, Vermont*, 1998; reported in D. J. Kreiger. The Economic Value of Forest Ecosystem Services: A Review (Washington, DC: The Wilderness Society, 2001).

80 Secretariat of the Convention on Biological Diversity. *The Value of Forest Ecosystems*, Technical Series #4. (Montreal: Secretariat of the Convention on Biological Diversity, 2001). Carbon storage and sequestration, p. 23+.

81 R. Clarkson. *Estimating the Social Cost of Carbon Emissions* (London: Department of the Environment, Transport and the Regions, 2000). (Conversion rate for US dollars to Cdn dollars is median price = 1.20440 [bid/ask], Friday March 11, 2005. From FXConverter™: Classic 164 Currency Converter © 1997-2005 by OANDA.com, http://www.oanda.com/convert/classic.)

82 R. Tol, S. Fankhauser, R. Richels, and J. Smith. "How Much damage Will Climate Change Do? Recent Estimates," *World Economics* 1 (2000): pp. 179-206. (Conversion rate for US dollars to Cdn dollars is median price = 1.20440 [bid/ask], Friday March 11, 2005. From FXConverter™: Classic 164 Currency Converter © 1997-2005 by OANDA.com, http://www.oanda.com/convert/classic.)

83 Secretariat of the Convention on Biological Diversity. *The Value of Forest Ecosystems* (Conversion rate for US dollars to Cdn dollars is median price = 1.20440 [bid/ask], Friday March 11, 2005. From FXConverter™: Classic 164 Currency Converter © 1997-2005 by OANDA.com, http://www.oanda.com/convert/classic.)

84 The global cost estimate is reported by United Nations Environment Programme. "Impact of Climate Change to Cost the World $US 300 Billion a Year," news release, February 3, 2001. Cost per tonne per year is total global cost divided by global carbon emissions (year 2000; 6.611 billion tonnes), http://www.unep.org/Documents/Default.Print.asp?DocumentID=192&ArticleID=2758. The value per tonne of carbon is estimated based on the total annual cost, $304.2 billion and the total 2000 global carbon emissions due to fossil fuel use: 6.611 billion tonnes; see G. Marland, T. A. Boden, and R. J. Andres. "Global, Regional and National CO_2 Emissions," in *Trends: A Compendium of Data on Global Change* (Oak Ridge, TN: Carbon Dioxide Information Analysis Centre, Oak Ridge National Laboratory, US Department of Energy, 2003). (Conversion rate for US dollars to Cdn dollars is median price = 1.20440 [bid/ask], Friday March 11, 2005. From FXConverter™: Classic 164 Currency Converter © 1997-2005 by OANDA.com, http://www.oanda.com/convert/classic.)

Second, the cost of climate change can also be estimated based on carbon fees. All Scandinavian countries have introduced a carbon fee (i.e., a tax) on fossil fuel to reduce the emission of the climate gas CO_2. Solberg uses Norway's carbon fee (approximately US$49/t$CO_2$, or Cdn$16.08/tC) as a proxy for the social cost of fossil fuels.[85] Solberg explains that the fee is an emission cost that provides a corresponding benefit for absorbing atmospheric CO_2 in forest biomass. His study shows that this benefit corresponds to a net economic value of carbon sequestration in forest biomass 2 to 30 times higher, depending on interest rate used, than the net value of timber as raw material for the forest industry in Norway (which has one of the highest timber prices in the world). Solberg notes that in order to stabilize the CO_2 emissions in Norway, the fee on CO_2 emissions would be at least twice as high as the above estimates.

Third, the value of carbon can be estimated based on replacement costs. A recent University of Saskatchewan study that assessed the carbon sequestered in protected areas in Canada reviewed several approaches to carbon valuation, including the alternative cost method, the marginal social opportunity cost method, the quasi-market method, the replacement cost method, and the substitute cost method. The authors selected two conservative median values. The first median value ($17.50/tC) was based on the replacement cost of carbon (i.e., afforestation on marginal agricultural land). The second median value ($16.25/tC) was based on the substitute cost of carbon (i.e., reforestation).[86]

Fourth, the value of carbon can be estimated based on carbon credit trading. Trading value in a "carbon market" refers to the sums of money that corporations or governments are willing to invest to sequester carbon or prevent its emission. It was estimated that without limitations on worldwide carbon trading, carbon credits would exchange at just under US$10 per tonne of carbon.[87] Currently, the price for one carbon allowance in the European market is approximately 17.37 euros per tonne of CO_2, which equates to Cdn$27.45 per tonne of CO_2 or Cdn$7.48 per tonne of carbon.[88]

Lastly, the value of carbon can be estimated based on the cost of timber income forgone in lieu of protecting the carbon stored in forest ecosystems. Haener and Adamowicz estimated the value of carbon sink functions for a boreal forest management area in Alberta, Canada. They calculated the carbon sequestered per tonne of net change in biomass after harvest, land use changes, and fire, using Hulkrantz's approach, which estimates the opportunity costs of storing fixed carbon as the timber income forgone. Haener and Adamowicz used a range of values from $0.34 to $16.60 per tonne of carbon (1996$) relative to the annual net carbon sequestered.[89]

85 B. Solberg. "Forest Biomass as Carbon Sink—Economic Value and Forest Management/Policy Implications," Special Issue, *Critical Reviews in Environmental Science and Technology* 27, 1997. In Norway, the fee is 0.82 NOK (or about US$0.12) per litre of gasoline, equivalent to 343 NOK (or US$49) per ton CO_2 (Conversion rate for US dollars to Cdn dollars is median price = 1.20440 [bid/ask], Friday March 11, 2005. From FXConverter(tm): Classic 164 Currency Converter ©1997-2005 by OANDA.com, http://www.oanda.com/convert/classic.)

86 Kulshreshtha et al. *Carbon Sequestration in Protected Areas of Canada*.

87 Note: this may change with the implementation of the Kyoto Protocol.

88 European Union Price Assessment for carbon emissions trading, April 4, 2005, http://pointcarbon.com (global provider of independent analysis, news, market intelligence, and forecasting for emerging carbon emission markets). Since April, there has been an upward trend in the price of carbon trading according to the European Union Price Assessment. On March 24, 2005, the trading price was 14.11 euros/tCO_2 (Cdn$6.07/tC) and on May 31, 2005, the trading price was 19.60 euros/tCO_2 (Cdn$8.44/tC). (Conversion rate for euros to Cdn dollars is median price = 1.58004 [bid/ask]; Friday March 28, 2005. From FXConverter™: Classic 164 Currency Converter © 1997-2005 by OANDA.com, http://www.oanda.com/convert/classic.)

89 M. K. Haener and W. L. Adamowicz. "Regional Forest Resource Accounting: A Northern Alberta Case Study," *Canadian Journal of Forestry Research* 30 (2000): pp. 264-273.

Garth Lenz

The Value of Carbon

The importance of ecosystems as a store or deposit of carbon is significant not only to Canada's future well-being, but to citizens across the globe. We have estimated that, for example, Canada's boreal region holds the equivalent of 303 years of Canada's total carbon emission in 2002, or 7.8 years of the world's total carbon emissions (67 billion tonnes of carbon, including forests and peatlands).[91] If reinsurance company Munich Re were to apply a shadow value to the total carbon stored by Canada's boreal region, then the company might estimate the boreal region's "carbon bank account" (including both forests and peatlands) to be worth $3.7 trillion ($55.42 per tonne of carbon). While this is hypothetical, it does point to the important value of carbon stores.

The value of Canada's boreal forest as a sustained storehouse of carbon, and its continued vitality and capacity to absorb anthropogenic emissions of carbon annually are critical to the well-being of all of humanity, not just Canadians. Indeed, the world may be willing to pay a price for ensuring Canada's boreal carbon budget remains healthy and in a net surplus (net sink) condition.

Table 18: Estimated Values for Forest Ecosystem Carbon Stored in Canada's Boreal Forests[A]

Carbon Valuation Method (author[s] of study)	Value per Tonne of Carbon	Total Value (billions, 2002$)	Value per Hectare (2002$)[b]
Market Price			
Carbon emissions trading price $ (EU assessment value; April 4, 2005)	$ 7.48 (2005$)	$333.5	$1,500
Replacement Cost			
Replacement cost of afforestation on marginal agricultural land-median value (Kulshreshtha et al. 2000)	$17.50 (2000$)	$849.2	$3,227
Carbon Tax as Proxy			
Norway's carbon fee on fossil fuel emissions as proxy of social cost (Solberg 1997; US$49/t$CO_2$)	$16.08 (1997$)	$823.3	$3,402
Climate Change Damage as Risk to Global Insurance Sector			
Estimated cost of damages due to climate change as risk to global insurance sector (Munich Re/UNEP FI 2001)	$55.42 (2001$)	$2,659.0	$10,989
Social Value for Costs of Climate Change			
UNEP global climate change damage estimate (Clarkson 2000)	$40.95 (2000$)	$1,987.3	$8,212
Opportunity Cost of Timber Income Forgone			
Estimated average opportunity cost of timber income forgone (Haener and Adamowicz 2000)	$8.47 (2000$)	$411.0	$1,699
RANGE OF CARBON VALUES			
Total Range of Values	$7.48 to $55.42	$333.5 to $2,659.0	$1,500 to $10,989

a Estimated carbon based on Canada's Forest Inventory, 2001 (forest land only). All figures in Canadian dollars. Forest carbon estimates based on stocked forest land area for Boreal and Taiga ecozones. The total area used is 212,156,000 ha (http://nfi.cfs.nrcan.gc.ca/canfi/data/ecozones-small_e.html); and the estimated carbon content for the ecosystem is 36,215,029,000 tonnes of carbon (includes aboveground and below-ground biomass and dead organic matter). The biomass conversion estimates are from the Carbon Budget Model of Canada's Forests (Boreal West estimates).

b Note that value per hectare is calculated using estimated value divided by the boreal forest land base (241,985,000 hectares).

Using the above sources, a range of values for carbon can be compiled to represent the market (i.e., carbon emissions trading) and non-market values (i.e., social costs, predicted damage costs; see Table 18). The values per tonne of carbon can be applied to estimate a value for the 47.5 billion tonnes of carbon stored in the boreal forest.[90] Based on the trading price for carbon, reported as the European Union Price Assessment ($7.48/tC), the boreal forest's total value for carbon stored is $333.5 billion ($1,500 per hectare). If the opportunity cost of the timber income forgone is used as a proxy for the value of carbon stored in the boreal forest, it would be worth $411.0 billion ($1,699 per hectare). Using the replacement cost of carbon through afforestation on marginal agricultural land, the total value of carbon stored is worth $849.2 billion ($3,227 per hectare). Similarly, the value of carbon stored by Canada's boreal forest is worth $823.3 billion ($3,402 per hectare) using Norway's carbon tax on the emission of CO_2 as a proxy. Based on the cost of climate change damages as forecast by the global reinsurance sector as a proxy, the value of the carbon stored in the boreal forest ecosystems is an estimated $2.7 trillion ($10,989 per hectare). In this last case, the value of carbon stored is significantly higher.

Therefore, the value of the carbon stored by Canada's boreal forests ranges from $333.5 billion to $2.7 trillion, or $1,500 to $10,989 per hectare, depending on the method used to estimate the value of carbon (see Table 18). It can be argued that some of the carbon values are additive. For example, the opportunity cost of timber income forgone only accounts for the loss in timber value if the carbon store (i.e., the forest area) is protected. However, the potential cost to society or global risk due to climate change damages is not included. In conclusion, we use a median value based on the replacement cost through afforestation as a conservative estimate for carbon valuation. Thus, the value of the boreal forest's carbon storage is an estimated $849.2 billion.

The full value of carbon stored by the boreal region includes peatlands, which are reported separately in the wetlands section (see section 4.2.3.5 *The Value of Boreal Wetland Ecosystem Services*; and Table 23). The importance of ecosystems as a store or deposit of carbon is significant not only to Canada's future well-being, but to citizens across the globe. We have estimated that, for example, Canada's boreal region holds the equivalent of 303 years of Canada's total carbon emission in 2002, or 7.8 years of the world's total carbon emissions (67 billion tonnes of carbon, including forests and peatlands).[91] If reinsurance company Munich Re were to apply a shadow value to the total carbon stored by Canada's boreal region, then the company might estimate the boreal region's "carbon bank account" (including both forests and peatlands) to be worth $3.7 trillion ($55.42 per tonne of carbon). While this is hypothetical, it does point to the important value of carbon stores.

The value of Canada's boreal forest as a sustained storehouse of carbon, and its continued vitality and capacity to absorb anthropogenic emissions of carbon annually are critical to the well-being of all of humanity, not just Canadians. Indeed, the world may be willing to pay a price for ensuring Canada's boreal carbon budget remains healthy and in a net surplus (net sink) condition.

4.2.3.1.3 *The Value of Climate Regulation: Carbon Sequestration*

Forests can act as either sinks, or sources, of atmospheric carbon in terms of the net annual flux of carbon amongst the various pools of carbon (i.e., biomass, soils, and atmosphere). Natural and human disturbance determine much of the amount of carbon exchanged. For example, the amount of carbon annually sequestered by and stored in forest ecosystems is strongly influenced by age distribution, growth processes, fire, insects, disease, and harvest. Whereas the carbon stored by an ecosystem is determined at a certain point in time based on the estimated carbon held in biomass and soils, the annual net carbon sequestered is the estimated net carbon taken up by biomass and soils each year after carbon release and carbon intake are accounted for.

Although the development of the Carbon Budget Model of Canada's Forests is not yet complete, current estimates of Canada's forest carbon budget based on the CBM-CFS2 simulation model have been modelled for the period from 1920 to 1994.[92] During this period, Canada's forests were an overall sink for atmospheric carbon, averaging 173 million tonnes of carbon

90 Forest ecosystem carbon storage estimate calculated using carbon storage estimates by ecozone for 1990-1994, from W. A. Kurz and M. J. Apps. "The Carbon Budget Model of the Canadian Forest Sector," *Ecological Applications* 9 (1999): 526-547, as reported by the Canadian Council of Forest Ministers. *Criteria and Indicators of Sustainable Forest Management in Canada*.

91 An estimated 47,493 million tonnes of carbon is stored in the ecosystem (biomass, soil, etc.) versus 156.9 million tonnes of carbon emitted by Canada in 2002.

92 An updated and more comprehensive model is currently being developed by the Canadian Forest Service.

per year.[93] However, the magnitude of the sink has been steadily declining. Kurz and Apps estimate that Canadian forests may have been a net source of CO_2 to the atmosphere after approximately 1980.[94] For example, between 1985 and 1989, Canadian forest ecosystems lost, on average, an estimated 69 million tonnes of carbon per year due to an increase in disturbances.

Furthermore, the carbon budget model indicates that Canada's boreal and subarctic forests were a net sink for carbon averaged over the simulation period, but they became a source of atmospheric carbon during the 1980s.[95] This change is mostly due to a large increase in fire and insect disturbances. Kurz and Apps indicated initially that harvesting played a small role in this change. However, more recent work shows that not all of the loss in carbon went to the atmosphere. An estimated 25 million tonnes of carbon per year has accumulated in forest product pools, resulting in a lower net release to the atmosphere of about 44 million tonnes of carbon per year during this period.[96]

In addition, a 1995 study analyzed the future carbon budgets of the Canadian boreal forests.[97] Over a 50-year simulation, the carbon budget of six scenarios for the boreal region ranged from a net source of 1.4 billion tonnes of carbon to a net sink of 9.2 billion tonnes of carbon, based on different assumptions of natural disturbances, rates of reforestation of disturbed land, and conversion of non-stocked to productive forest stands.

Estimates of the average net annual sequestration rate in the boreal and subarctic forest carbon pools were not available in the published literature for the simulation period (1920 to 1994). Therefore, the Canada average, 173 million tonnes of carbon per year, was used to establish an average of 0.428 tonnes of carbon per hectare per year. We applied a range of carbon values, (outlined in section 4.2.3.1.2 *The Value of Climate Regulation: Carbon Storage*), to determine the annual net forest ecosystem carbon sequestration value. Using the European Union carbon trading price, cost of replacement value through afforestation, and the global cost estimate for the cost of climate change damages, the value, per hectare per year for carbon sequestration are $3.27, $7.03, and $23.96, respectively (2002$). Extrapolated to the boreal forest (242 million hectares), the total annual value is $791.3 million, $1.85 billion, and $5.8 billion, respectively (2002$).

We used the median value based on the replacement cost of carbon through afforestation to calculate the overall boreal ecosystem service values. Therefore, we adopted the total value of $1.85 billion per year. If we use the future scenario estimates for carbon sequestration rates over the next 50 years, then the value for the boreal region would range from a cost of $25 billion to a benefit of $162.7 billion (2002$).

4.2.3.1.4 *The Value of Boreal Forest Watershed Services*

Forested watersheds capture and store water, services that contribute to the quantity of water available, and the seasonal flow of water. They also help purify water by stabilizing soils and filtering contaminants. These services are important for agriculture, electricity generation, municipal water supplies, recreation, and habitat for fish and other wildlife species. Estimates for water quantity values focus primarily on stream flow and range from US$0.26 per acre-foot for electricity generation to as much as US$50 per acre-foot for irrigation and municipal use.[98]

Water quality is very important for municipal uses. For example, the US Environmental Protection Agency estimates that 3,400 public water systems serving 60 million people obtain their water from forested watersheds. The value of the purification services provided by forested watersheds is reflected in the costs that communities incur to protect their watersheds. For example, in 1997, New York City opted to invest US$1.5 billion in capital costs to protect the natural filtration system provided by the 80,000 acre forested watershed and the drinking water supply for nearly 10 million people, rather than construct an artificial water filtration plant estimated to cost as much as US$6 to US$8 billion plus annual maintenance costs

93 Canadian Council of Forest Ministers. Criteria and Indicators of Sustainable Forest Management in Canada.

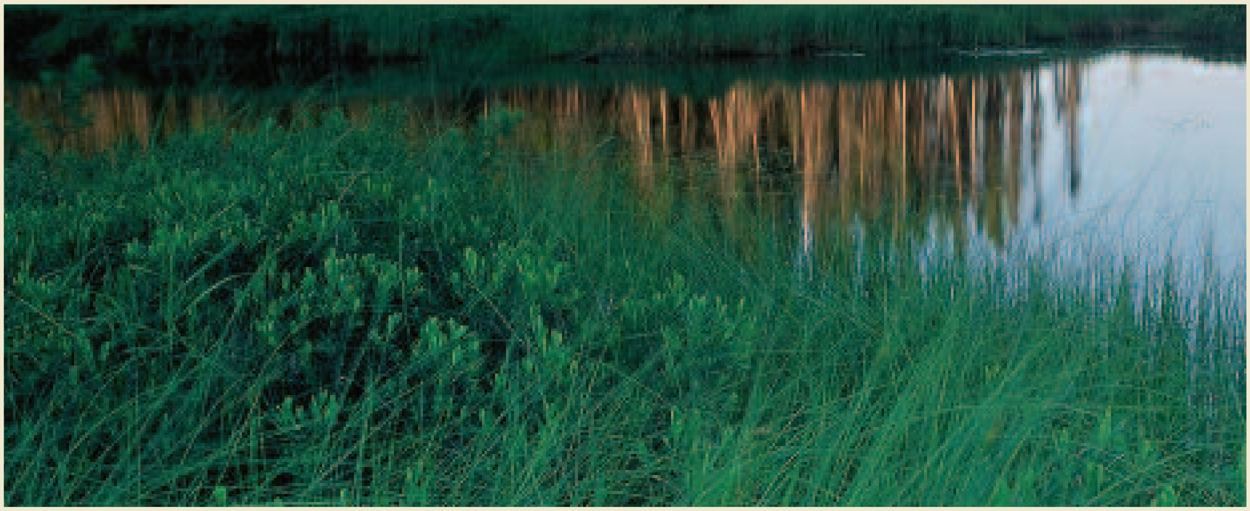
94 W. A. Kurz and M. J. Apps. "A 70-Year Retrospective Analysis of Carbon Fluxes in the Canadian Forest Sector," *Ecological Applications* 9 (1999): 526-547.

95 Canadian Council of Forest Ministers. Criteria and Indicators of Sustainable Forest Management in Canada: Technical Report 1997 (Ottawa: Natural Resources Canada, Canadian Forest Service, 1996), Element 4.1, http://www.ccfm.org/ci/tech_e.html.

96 Apps et al., "Carbon Budget of the Canadian Forest Product Sector."

97 W. A. Kurz, and M. J. Apps. "An Analysis of Canadian Boreal Forests," *Water, Air, and Soil Pollution* 82 (1995): pp. 321-331.

98 J. Sedell, M. Sharpe, D. Dravnieks Apple, M. Copenhagen, and M. Furniss. *Water and the Forest Service.* FS-660. (Washington, DC: United States Department of Agriculture, Forest Service, 2000). Recreational use: $10 per acre-foot or less.



Garth Lenz

of US$300 to US$500 million.[99] As a result, the upstate watershed natural systems that had delivered exceptionally pure water for more than a century continue to supply New York's tap water without having to pass through a filtration plant.

Based on results from our spatial analysis of Environment Canada's Municipal Use Database (MUD), we extracted the value of municipal water use in communities in the boreal region.[100] The total municipal water use is an estimated 368.1 million cubic metres per year for the boreal region (population of 1,426,535). Unfortunately, the geocoding of the MUD is currently incomplete and, therefore, the total water use and the value of municipal water use are underestimated. The US Forest Service has estimated the value of municipal water use at US$50 per acre-foot (Cdn$0.05 per cubic metre).[101] Transferring this average value, the economic value of water flow for municipal use in the boreal region is at least Cdn$18.4 million per year (2002$).

4.2.3.1.5 *Soil Stabilization and Erosion Control*

Forest vegetation helps stabilize soils, and therefore, reduces erosion and sedimentation. The costs associated with erosion include reduced soil productivity, damaged roads and structures, filled ditches and reservoirs, reduced water quality, and harm to fish populations. The estimated values for soil stabilization and erosion control are revealed by the costs incurred due to sedimentation. In the United States, cost estimates due to sedimentation include US$1.94 per ton of sediment associated with logging-induced erosion and US$5.5 million annually in Oregon's Willamette Valley.[102] Information on sedimentation or erosion rates in the boreal region is not available, and therefore no value/cost was applied to these items in this study.

4.2.3.1.6 *Air Quality*

Trees trap airborne particulate matter and ozone, and thereby improve air quality and human health. One US study shows that 500,000 mesquite trees (once mature) remove 6,500 tons of particulate matter annually, providing a value of US$4.16 per tree.[103] Data on tree cover in and nearby urban areas of the boreal region were not available, and therefore no value was applied to this attribute in this study.

4.2.3.2 The Value of Biodiversity

4.2.3.2.1 *The Value of Natural Pollination and Pest Control*

Biological diversity is important in terms of its role as a storehouse of genetic material. Such information is used to breed plants and animals, to develop natural pest and disease control, and for valuable pharmaceutical products. Few studies have addressed the value of biological diversity in forest ecosystems. However, the estimated cost to US agriculture for the replacement of natural pest control services from all natural ecosystems by chemical pesticides is estimated at

99 Daily, G.C., and Ellison, K. 2002. The New Economy of Nature: The Quest to Make Conservation Profitable. Island Press. Washington, D.C.; Kreiger, *The Economic Value of Forest Ecosystem Services.*

100 Municipal Water Use Database (MUD), 2001. The Canada-wide MUD dataset of 1,963 communities is missing geo-coordinates for 986 of those communities. GFWC managed to link the dataset to other datasets on populated places, but only could reduce that deficiency by 129, leaving 848 communities with no geo-coordinates. GFWC then extracted those communities within the Boreal/Taiga ecozones. These 269 communities represent a total population of 1,426,535 people and represent a total municipal water flow of 368,052,501 cubic metres^3 per year.

101 Sedell et al., *Water and the Forest Service.*

102 K. Moskowitz and J. Talberth. *The Economic Case Against Logging Our National Forests. Forest Guardians*. Santa Fe, NM, 1998.

103 J. F. Dwyer, E. G. McPherson, H. W. Schroeder, and R. A. Rowntree. "Assessing the Benefits and Costs of the Urban Forest," *Journal of Arboriculture* 18 (1992): pp. 227-234.

US$54 billion annually.[104] Likewise, the pollination services of natural ecosystems may provide benefits worth between US$4 billion and US$7 billion annually for the US agricultural sector.[105]

The US Forest Service has estimated that it would cost more than US$7 per acre (Cdn$21.84 per hectare) to replace the pest control services of birds in forests with chemical pesticides or genetic engineering. Similarly, it has been estimated that birds such as the evening grosbeak predation on western spruce budworm resulted in US$1,820 of positive economic benefit per year per square kilometre (US$182,000 per hectare per year).[106] If the former value of birds for pest control is applied per hectare of boreal forest land, then boreal birds provide a service worth $5.4 billion per year (2002$).

4.2.3.2.2 *The Value of Non-Timber Forest Products*

Biological diversity is also important for non-timber commercial forest products and subsistence foods and materials. Forests produce many commercially valuable products other than timber. Examples of non-timber forest products include: maple products, berries, mushrooms, peat, floral greens, medicinal plants, edible plants (e.g., wild rice), and wildlife species that can be used for food or medicinal, ornamental, or industrial purposes. These products contribute significant value to the economy. For example, the total market value of harvested non-timber products from national forests in the US Pacific Northwest was about US$300 million in 1992.[107]

In Canada, the value of non-timber forest products was roughly estimated at $241 million per year in 1997.[108] In addition, the value of wild rice is approximately $2 million per year (2001$).[109] In total, the economic value is an estimated $243 million per year. According to researchers at the Canadian Forest Service (CFS), the current estimated economic output of forest-based foods ranges from $725 million to $1.33 billion, and the future economic potential is between $2 and $7.4 billion per year.[110] For example, edible mushrooms could contribute as much as $115 million to the Canadian economy.

We roughly estimated that the value of non-timber forest products for the boreal region is at least $79 million per year (2002$), based on an estimated 60 percent of the more conservative (1997) national estimate for mushrooms, berries, and wild rice harvests (this figure excludes maple products).[111] Sixty percent was used to estimate the proportion of the national NTFP (non-timber forest products) economic value for the boreal region based on the approximate proportion of timber value from the boreal region in section 4.2.1 *Market Values of Boreal Natural Capital* of our report.

4.2.3.3 The Value of the Boreal Region to Aboriginal Peoples and Subsistence Living

Forests are also sources of subsistence foods, especially in the North. Canada's boreal region is home to over 4 million Canadians, including 634 Aboriginal communities with over 200,000 people.[112] Over the millennia, Aboriginal peoples have developed valuable traditional knowledge that has balanced conservation with sustenance in the boreal region. The Boreal Shield ecozone alone is home to the majority of Aboriginal communities in Canada, with a full 80 percent of the Aboriginal population in Canada living in this ecozone.[113] Some Aboriginal communities that inhabit the frontier boreal forest of northern Canada still practise their traditional way of life and depend upon the forests for their food, medicines, and economic livelihood.

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104 Moskowitz and Talberth, *The Economic Case Against Logging our National Forests.*

105 Ibid.

106 J. Y. Takekawa and E. O. Garton. 1984. "How Much Is an Evening Grosbeak Worth?" *Journal of Forestry* 82 (1984): pp. 426-428.

107 Moskowitz and Talberth, *The Economic Case Against Logging our National Forests.*

108 Ontario Forest Research Institute, Ministry of Natural Resources. *Non-Timber Forest Products in Ontario: an Overview*, Forest Research Information Paper No. 145. (Sault Ste. Marie, ON: Ontario Forest Research Institute, Ministry of Natural Resources, 1999), p.3; reported by Saskatchewan Environmental Society. (Non-Timber Forest Products: Economic Development while Sustaining our Northern Forests, http://www.environmentalsociety.ca/issues/forests/ntfp.pdf)

109 P. M. Catling and E. Small. "North American Wild Rice (*Zizania* Species)—A Wild Epicurean Crop," *Biodiversity* 2, no. 3 (2001): pp. 24-25, http://www.tc-biodiversity.org/sample-wildrice.pdf.

110 Canadian Forest Service. *The State of Canada's Forests 2004-2005: The Boreal Forest* (Ottawa: Natural Resources Canada, 2005), http://www.nrcan-rncan.gc.ca/cfs-scf/national/what-quoi/sof/latest_e.html.

111 This estimate was based on 60 percent of the total value. Sixty percent was used as an estimate based on the proportion estimated in the preceding section of this study for the boreal region's forestry GDP as there was no proportion specified for the boreal region.

112 Analysis by Global Forest Watch Canada, 2003, based on Statistics Canada's 1996 Aboriginal Population Census. The communities for which data was gathered and analyzed for the GFWC report are found in "Aboriginal Communities in Forest Regions in Canada: Disparities in Socio-Economic Conditions."

113 Retrieved August 10, 2005 from Boreal Forest Network website http://www.borealnet.org.

There is inadequate information available regarding food use by native communities in forest regions. However, a recent report on Alberta's boreal region states that subsistence values range from $5,000 to $11,000 per household, depending on the location and the variety of activities studied.[114] According to the 1996 Census, the Aboriginal population in Canada's boreal region is 201,704, and the number of households is 51,166. If we apply the subsistence values from the Alberta report, then the subsistence value for Aboriginal peoples in Canada's boreal region is estimated between $261.4 million (2002$) and $575.1 million (2002$).

4.2.3.4 Passive Values: Conservation of Biodiversity

Forests hold cultural values, or what economists call *passive use values*, which include endangered species habitat, the aesthetic value of forest scenery, and values associated with a region's cultural heritage. For example, the values attached to the Pacific Northwest old-growth forests for northern-spotted owl habitat range from US$35 to US$95 per household per year.[115] Passive values also include the value of knowing that forests exist now and in the future. For example, the willingness to pay (WTP) to protect old-growth forests west of the Cascade Mountains is US$48 to US$144 per household per year; it is US$14 to US$92 per household per year to protect wilderness in the Rocky Mountain region.[116]

The protection of biodiversity includes maintaining effective habitat. Although it is difficult to value biodiversity, an Alberta study examined the WTP for habitat conservation by Saskatchewan households.[117] The study found that Saskatchewans were willing to pay an average of $14.66 per household per year for caribou conservation, based on an open-ended WTP question, compared with a mean WTP of $97.99 per household, based on a discrete choice questionnaire.[118] Similarly, an Edmonton household survey by Haener and Adamowicz found the median WTP for Edmonton households for old-growth forest protection was between $89 and $122 per year (1998$).[119] We extrapolated the low-end WTP from the Saskatchewan study ($16.81 per household per year; 2002$) to estimate a passive value for the boreal region. Assuming that 50 percent of boreal households would be willing to pay the same amount per year for the conservation of biodiversity, then the passive value would be $12 million per year for habitat conservation (2002$).[120]

4.2.3.5 The Value of Boreal Wetland Ecosystem Services

The National Wetlands Working Group defines wetlands as "areas saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various types of biological activity that are adapted to a wet

114 Haener and Adamowicz, "Regional Forest Resource Accounting"—based on replacement values obtained by inputting prices using the closest substitutes to harvest products that are available in the nearest market.

115 Kreiger, *The Economic Value of Forest Ecosystem Services.*

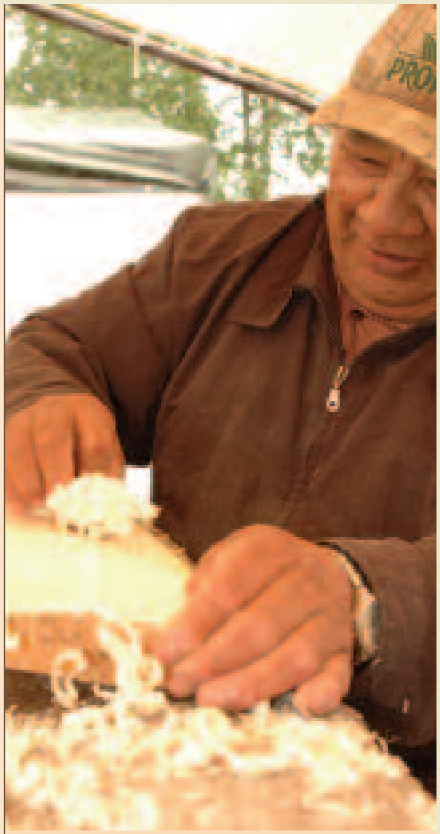
116 Ibid.

117 M. Tanguay, W. L. Adamowicz, P. Boxall, W. Phillips, and W. White. *A Socio-economic Evaluation of Woodland Caribou in Northwestern Saskatchewan* (Edmonton: University of Alberta, Department of Rural Economy, 1993), Project Rep. No. 93-04.

118 Ibid.

119 Haener and Adamowicz, "Regional Forest Resource Accounting."

120 Boreal human population is 3,611,498 (Statistics Canada. 2000. Human Activity and the Environment. Division. System of Natural Accounts. Catalogue no. 11-509-XPE); estimated number of households in the boreal region is 1,389,038 (based on the Canadian average of 2.6 people/household; http://www.statcan.ca/english/Pgdb/famil53_96a.htm . Passive value is the low-end willingness to pay (WTP) value for the conservation of caribou from a Saskatchewan study in 2002$ see Tanguay et al., *A Socio-economic Evaluation of Woodland Caribou.*



Natasha Moine

Aboriginal People and Boreal Values

Canada's Boreal is the cultural, spiritual and economic base for approximately 600 Aboriginal communities. Virtually the entire region is subject to historic treaties or modern day land claims by Aboriginal peoples to their traditional territories.

Over the millennia, Aboriginal peoples have developed valuable traditional knowledge that has balanced conservation with sustenance in the boreal region.

There is a growing respect for the expertise and understanding that Aboriginal people have acquired over countless generations through observation and experience on the land.

Garth Lenz

environment."[121] Wetlands cover approximately 14 percent of the Canadian landscape, with 90 percent of these wetlands being peatlands.[122] Such areas were once viewed as wastelands that needed to be drained for other land use. Today, there is widespread recognition of their valuable ecosystem services, however much debate remains over the highest economic use for wetland areas and the extent to which resources should be allocated for their protection and restoration.[123]

Wetlands are an integral component of the boreal region. The vast majority of boreal wetlands are peatlands. Wetlands are an excellent example of the types of goods and services that natural capital provides for society. Wetlands provide several ecosystem services including flood protection, water storage, water purification, carbon storage, food production, habitat for wildlife, and recreation. Wetlands are not isolated ecosystems. They are connected with the surrounding land and water, forming critical parts of our forests, watersheds, and coastal areas.

Wetlands at the headwaters of our river and stream systems are the source of our freshwater, and therefore affect the health and productivity of downstream human and freshwater communities. For example, they improve water quality by filtering and absorbing contaminants. They can reduce the nitrate and phosphorus that would flow into rivers and lakes by up to 80 percent and 94 percent, respectively.[124] This is an important service if one considers that up to half of the fertilizer nitrogen is lost in runoff after most applications.[125] This is also an important service because excessive nutrients reduce the availability of oxygen in water, which can kill fish (i.e., through eutrophication or excessive algae production). Such conditions also greatly reduce or eliminate opportunities for recreational use, and high nitrates make water unsafe to drink. Scientific studies also report that Canadian wetlands can retain or remove up to 70 percent of the sediments, 90 percent of the bacteria, and almost all the pesticides that enter them.

121 C. Tarnocai. Wetlands of Canada (Ottawa: Eastern Cereal and Oilseed Research Centre. Research Branch, Agriculture and Agri-Food Canada, 2001). Although peatlands functionally include all bog and fens, fens that have less than 40 cm peat depth are classified as mineral wetlands by Tarnocai (2001) for the purpose of calculating carbon.

122 Ibid.

123 R. T. Woodward and Y. Wui. "The Economic Value of Wetland Services: A Meta-analysis." *Ecological Economics* 37 (2001): pp. 257-270.

124 N. Olewiler. *The Value of Natural Capital in Settled Areas of Canada* (Stonewall, MB, and Toronto: Ducks Unlimited Canada and the Nature Conservancy of Canada, 2004); wetland plants can remove between 116 and 400 kilograms/hectare/year of phosphorus and 350 to 1,700 kilograms/hectare/year of nitrogen (i.e., duckweed); other plants can remove or degrade toxic compounds such as heavy metals and pesticides.

125 L. Ross. "Canada's Good Fortune: Putting a Price Tag on the Country's Wetlands," *Conservator*, Winter 2003: pp. 35-37 (Ducks Unlimited Canada).

Wetlands maintain our water supply and regulate water flow. Small wetlands recharge water supplies to aboveground waterbodies (such as rivers, lakes, and streams) and to groundwater. They control floods by storing large amounts of water. For example, one-half hectare of wetlands can store over 6,000 cubic metres of floodwater.[126] If a wetland is lost due to land-use changes, then the risk of floods and floodwater damage increases significantly.

Furthermore, wetlands, and peatlands in particular, provide sinks for atmospheric carbon dioxide (CO_2). They, therefore, play an important role in the global carbon cycle. Wetlands may store as much as 40 percent of global terrestrial carbon, with peatlands and forested wetlands being the most significant carbon sinks. For example, although peatlands cover only 3 percent of the world's land area, they are estimated to store over 25 percent of the soil carbon pool.[127]

Wetlands are widely used for recreational activities. Wildlife viewing/photography is one of the fastest growing recreational activities in Canada, and is a major activity in and around wetlands. Across North America, 60 million people watch migratory birds, and 3.2 million hunt ducks and geese annually, which generates US$20 billion each year in economic activity. Wetlands are popular destinations because they provide habitat for a wide variety of wildlife; in North America, wetlands are habitat for about 600 species. According to the Ramsar Secretariat, which manages the Ramsar Convention on Wetlands, freshwater fishing is entirely dependent on wetlands, and in the United States it has been estimated that half of the seawater catch is also associated with wetlands. This relationship is key to the 45 million Americans that take part in recreational fishing, spending a total of US$24 billion each year.

Wetlands provide many commercial products such as fish, shellfish, blueberries, cranberries, timber, wild rice, and medicines. And, wetlands are particularly important for commercial fisheries because they depend on wetlands for spawning and nurseries, and for the food for growing stocks.

Several classes of wetlands are found in the boreal region. These include bogs, fens, marshes, swamps, and shallow open water.[128] However there are two major types of wetlands: (1) mineral wetlands, which contain less than 40 centimetres of peat; and (2) organic wetlands, known as peatlands, which contain more than 40 centimetres of peat (organic material).[129]

4.2.3.5.1 *Mineral Wetland (Non-Peatland) Ecosystem Service Values*

According to a 2001 wetland inventory, Canada's boreal non-peatland wetlands (or mineral wetlands) cover 2.8 million hectares (see Table 19)[130] of the total 86.0 million hectares of wetlands across the region (also see section 4.2.3.5.2 *Peatland (Organic Wetlands) Ecosystem Service Values*). The boreal region has the largest area of wetlands

Table 19: Area of Mineral Wetlands (Non-Peatland) in Canada's Boreal Region by Class of Wetland

Ecoclimatic Region	Mineral Wetlands (Non-Peatland Wetlands) (square Kilometres)				
	Fens[a]	Marshes	Swamps	Shallow Open Water	Total
Boreal	340	16,277	497	4,875	21,989
Subarctic Low	1,246	0	2	4,618	5,866
Subarctic Cordilleran	452	0	0	61	513
Total area (square kilometres)	2,038	16,277	499	9,554	28,368
Total area (hectares)	203,800	1,627,700	49,900	955,400	2,836,800

Source: C. Tarnocai. *Wetlands of Canada* (Ottawa: Eastern Cereal and Oilseed Research Centre. Research Branch, Agriculture and Agri-Food Canada, 2001).

a Only fens that have < 40 cm peat depth are included in Table 19; fens with > 40 cm peat depth are included in Table 22.

126 Olewiler, *The Value of Natural Capital in Settled Areas of Canada*; and Ross, "Canada's Good Fortune."
127 Ramsar Convention Bureau. *Background Papers on Wetland Values and Functions: Climate Change Mitigation* (Gland, Switzerland, 2000), http://www.ramsar.org/info/values_climate_e.htm.
128 For definitions, please see C. Tarnocai. *Wetlands of Canada* (Ottawa: Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, 2001).
129 Ibid.
130 Ibid.

and the highest proportion of wetlands (57 percent) when compared with the other ecoclimatic regions of Canada.

Placing a value on wetland ecosystem services is a challenge due to the nature of the services themselves. Wetland ecosystem services typically do not have a market value and, therefore, they must be accounted for using non-market valuation techniques. Reviews of wetland valuation studies document many wetland valuation studies over the last three decades.[131] According to one review, wetland values range greatly-from US$0.06 per acre to US$22,050 per acre.[132] Another study took the values from 42 studies to develop average ecosystem service values including 13 freshwater wetland sources. The average values for freshwater wetlands ranged from US$7,684 to US$31,772 per acre.[133] A recent Canadian study for settled areas reported annual values ranging from Cdn$5,792 to Cdn$24,330 per hectare of wetland.[134] However, not all boreal wetlands provide all the services evaluated for wetlands in the above studies. The values determined include ecosystem services such as fish, shellfish, waterfowl, mammal and reptile habitat; water supply; erosion, wind, and wave barrier; storm and flood control; and recreational opportunities.

One of the factors causing such a wide range of values for wetlands is the difference in types of wetlands and their defining characteristics. In other words, different types of wetlands provide different types of services. For example, coastal wetlands provide shellfish for harvesting and coastal protection from erosion and rising sea levels; peatlands provide market revenues due to peat harvesting, and non-market values for carbon storage; and headwater wetlands provide water treatment services and protection from flooding. Second, studies tend to be determined by the major service(s) provided according to the dominant nearby human land use. For instance, if nearby human activities are primarily agricultural, then values may focus on the removal of excessive nutrients and other contaminants from the water supply. Third, studies vary in the number of values included in their research. Furthermore, some valuation techniques focus on total economic

Table 20: Average Wetland Ecosystem Service Values from Wetland Valuation Meta-Analysis

Wetland Function	US$/hectare/year (2000$)	Cdn$/hectare/year (2002$)
Flood control	464	571.02
Recreational fishing	374	460.27
Amenity/recreation	492	605.48
Water filtering	288	354.43
Biodiversity	214	263.36
Habitat nursery	201	247.36
Recreational hunting	123	151.37
Water supply	45	55.38
Materials	45	55.38
Fuel wood	14	17.23
Total	2260	2,781.28

Source: K. Schuyt and L. Brander. *Living Waters: The Economic Values of the World's Wetlands* (Gland, Switzerland: World Wildlife Fund, 2004).

131 R. E. Heimlich, K.D. Weibe, R. Claassen, D. Gadsy, and R.M. House. *Wetlands and Agriculture: Private Interests and Public Benefits* (Washington, DC: Resources Economics Division. E.R.S. USDA, 1998), Agricultural Economic Report 765.10

132 The most well-known study by Costanza et al. (in 1997) on the value of the world's ecosystems determined a general annual value for wetland services at US$14,785 per hectare. See Robert Costanza, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton, and Marjan van den Belt. "The Value of the World's Ecosystem Services and Natural Capital," Nature 38, no. 15 (1997): pp. 253-259.

133 K. Breunig. *Losing Ground: At What Cost?: Changes in Land Use and Their Impact on Habitat, Biodiversity, and Ecosystem Services in Massachusetts. Technical Notes*, 3rd ed. of the Losing Ground Series (Lincoln, MA: Mass Audubon, 2003) (standardized to US 2001 dollars), http://www.massaudubon.org/losingground; ecosystem services included in the valuation are disturbance prevention, freshwater regulation and supply, waste assimilation, aesthetic/amenity, and soil retention. Valuation studies that were selected were (a) peer reviewed and published in recognized journals; (b) focused on temperate regions in North America or Europe; and (c) focused primarily on non-consumptive use.

134 Olewiler, *The Value of Natural Capital in Settled Areas of Canada*; dollar amounts were adjusted by author for inflation, assuming an inflation rate of 2% per year since the mid-1990s, and converted to Canadian dollars using a Canadian-US exchange rate of 1.35.

value by adding up a set of relevant values, and some only on one particular value. Fourth, studies vary by the valuation method and economic theory underlying the valuation used. Contingent valuation determines a community's willingness to pay, whereas replacement cost valuation estimates an alternative way of obtaining a service such as the cost of chemical or mechanical substitutes. Finally, some studies report direct total revenues (e.g., market value of products extracted), while other studies estimate the economic surplus or the marginal value of services according to standard economic theory.[135]

Site-specific valuation studies would be the best method to value Canada's boreal wetlands. However, such studies have not yet been conducted in this region. Therefore, estimates must be made using benefits transfer, i.e., prediction of value based on previous studies. In order to estimate wetland values for the region, we chose to extrapolate average wetland values by wetland function from a meta-analysis of 89 wetland valuation studies.[136] We chose this meta-analysis because of the great range of estimates for the ecosystem service values of wetlands, as outlined above. Given the extensive review taken by the meta-analysis, it is the most comprehensive to date. In addition, the average values provide estimates for the cost of replacing wetland functions globally (see Table 20).

Values for the following services provided by wetlands were chosen as most applicable to the boreal region because they are generally universal benefits from wetlands: flood control, water filtering, and biodiversity. For example, the boreal region has the largest area of wetlands of any ecosystem in the world, and therefore, is also breeding ground for 12 to 14 million waterfowl and untold millions of shorebirds.[137] Results from the meta-analysis provide average wetland values as follows: $571.02 per hectare per year for flood control; $354.43 per hectare per year for water filtering; and $263.36 per hectare per year for biodiversity (2002$Cdn; see Table 20). Using these values, Canada's boreal mineral wetlands (excludes peatlands) contribute services worth Cdn$3.4 billion dollars per year (2002$; see Table 21).

4.2.3.5.2 *Peatland (Organic Wetlands) Ecosystem Service Values*

In the Canadian boreal region, there are 83.2 million hectares of peatlands according to the results from our spatial analysis of Canada's Peatland Database.[138] Figure 4 illustrates the distribution of peatlands in the boreal region. Peatlands provide an invaluable service by storing large amounts of carbon. In order to estimate the carbon stored in the boreal region's peatlands, we used the average carbon density for peatlands by ecozone (i.e., Boreal East, Boreal West, and Taiga) reported by a University of Saskatchewan report that analyzed the value of carbon in the protected areas of Canada. As a result, we estimated that boreal peatlands hold 19.5 billion tonnes of carbon (see Table 22).[139]

Table 21: Canada's Boreal Mineral Wetland Ecosystem Service Values

Wetland Function	Values		
	millions (2000$)	millions (2002$)	$/hectare/year (2002$)
Flood control	1,585	1,620	571.02
Water filtering	984	1,005	354.43
Biodiversity	731	747	263.36
TOTAL	3,300	3,372	1,188.81

Source: Based on average wetland function values from K. Schuyt and L. Brander. *Living Waters: The Economic Values of the World's Wetlands* (Gland, Switzerland: World Wildlife Fund, 2004).

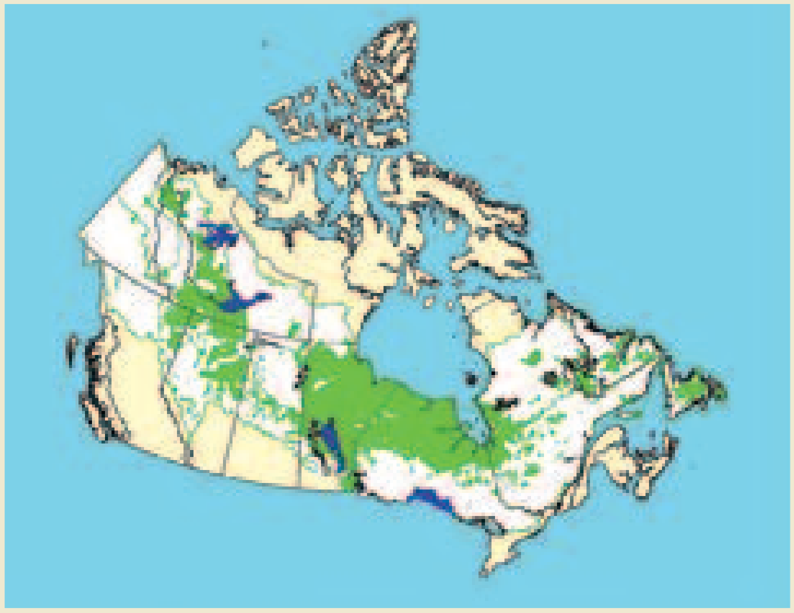
135 Woodward and Wui, "The Economic Value of Wetland Services."
136 K. Schuyt and L. Brander. *Living Waters: The Economic Values of the World's Wetlands* (Gland, Switzerland: World Wildlife Fund, 2004).
137 Canadian Forest Service. *The State of Canada's Forests* 2004-2005.
138 Peter Lee, Global Forest Watch Canada analysis, sent March 1, 2005. Peatland area data for the Boreal and Taiga ecozones were extracted using spatial analysis of geo-coded data from Canada's Peatland Database.
139 Kulshreshtha et al. *Carbon Sequestration in Protected Areas of Canada.*

Table 22: Canada's Boreal Wetlands by Ecozone-Area and Carbon Content of Peatlands

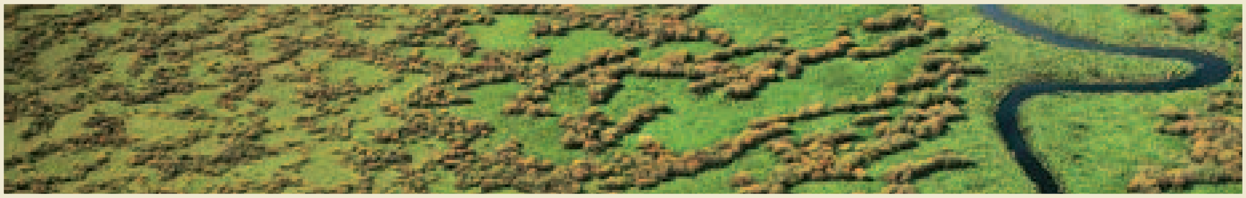
Ecozone	Peatland Area		Carbon Content
	(square kilometres)	(hectares)	(millions of tonnes)
Boreal Cordillera	1,775	177,500	83.8
Boreal Plains	98,161	9,816,100	2,559.1
Boreal Shield	245,154	24,515,400	6,391.2
Hudson Plains	248,686	24,868,600	6,483.2
Taiga Cordillera	67	6,700	1.1
Taiga Plains	141,100	14,110,000	2,371.9
Taiga Shield	97,054	9,705,400	1,631.5
TOTAL	831,998	83,199,800	19,521.7

Source: Peatland area: Analysis by Global Forest Watch Canada, March 1, 2005.

Figure 4: Area of Peatlands in Canada's Boreal Region



Source: **Global Forest Watch Canada, 2005**



Garth Lenz

A median value ($17.50 per tonne of carbon) based on the replacement cost method (i.e., afforestation on marginal agricultural land), was used to evaluate boreal forest carbon in a preceding section (see section 4.2.3.1.2 *The Value of Climate Regulation: Carbon Storage*). The annual net carbon sequestered by boreal peatlands is an estimated 21.4 million tonnes. This estimate is based on Canada's carbon budget, which reports that an annual net 257,485 tonnes of carbon is sequestered per hectare by peatlands.[140] Thus, we estimate the annual value at $383 million using the above replacement cost ($17.50 per tonne of carbon).

If we apply the same replacement value, the value of peatland carbon storage in Canada's boreal region is an estimated $349 billion ($4,195 per hectare). This value reflects the carbon stored or stock value (as opposed to the annual net carbon sequestered), and therefore, is not included in the total sum of ecosystem services. Similarly, we applied the trading price of carbon and an estimated value of the risks of climate change damage costs for forest carbon valuation. Based on the European Union's carbon emissions trading price, ($7.48 per tonne of carbon),[141] the boreal peatland carbon stores are worth $137 billion ($1,648 per hectare). If the value of the carbon stored in boreal peatlands is based on the cost of replacement through afforestation, the value is $349 billion ($4,195 per hectare). The value of peatland carbon storage based on the cost of climate change damages as forecast by the global reinsurance sector as a proxy[142] is significantly higher: an estimated $1,093 billion per year ($13,137 per hectare per year).

Peatlands are also valuable for their water regulation and water filtering services. Based on the average wetland values reported above in Table 20, flood control services are an estimated $46.5 million per year, and water filtering services are an estimated $28.9 million per year (2000$); a total of $77 million per year (2002$).

The representative values for Canada's boreal wetlands are large, yet incomplete. Due to a lack of information, monitoring, and knowledge, we do not know the full extent of their ecosystem services. Nor is it possible to fully value their services, given the fact that the total value of the world's ecosystems is infinite—for without them, we could not live. However, estimates of the values we can determine are useful for land-use planning and policy decision-making. In making decisions at the local level or management unit level, it is useful to consider the value of carbon storage per hectare of peatland. Given the values used above, the value of carbon storage by peatlands is estimated to be worth from $1,648 to $13,137 per hectare.

Although we do not have the information to determine how much of Canada's boreal wetlands have been lost due to human activities, it is important to consider Canada's wetlands in a global context. In all, 35 percent of the world's wetlands are in Canada's boreal region, and this figure includes over 40 percent of Canada's Wetlands of International Importance.[143] According to the Organisation for Economic Co-operation and Development, some estimates indicate that the world may have already lost 50 percent of its wetlands since 1900-much of which has occurred in northern countries.[144] In Canada, the National Wetlands Working Group reported that an estimated 65 percent of Atlantic tidal and salt marshes, 70 percent of the lower Great Lakes-St Lawrence River shoreline marshes and swamps, up to 71 percent of prairie potholes and sloughs, and 80 percent of Pacific coast estuarine wetlands have been converted to other uses-primarily agricultural drainage; diking; urban and industrial expansion; construction of ports, roads, and hydroelectric facilities;

140 W. A. Kurz, M. J. Apps, T. M. Webb, and P. J. McNamee. *The Carbon Budget of the Canadian Forest Sector: Phase I* Ottawa: Forestry Canada, 1992). Note: accounts for methane release.

141 European Union Price Assessment for carbon emissions trading, April 4, 2005, http://www.pointcarbon.com (global provider of independent analysis, news, market intelligence, and forecasting for emerging carbon emission markets).

142 The global cost estimate is reported by United Nations Environment Programme. "Impact of Climate Change to Cost the World $US 300 Billion a Year," news release, February 3, 2001, http://www.unep.org/Documents/Default.Print.asp?DocumentID=192&ArticleID=2758; The value per tonne of carbon is estimated based on the total annual cost, $304.2 billion and the total 2000 global carbon emissions due to fossil fuel use: 6.611 billion tonnes; see Marland et al., "Global, Regional and National CO2 Emissions."

143 Designated by the Ramsar Convention on Wetlands, http://www.ramsar.org.

144 OECD/IUCN. 1996. *Guidelines for Aid Agencies for Improved Conservation and Sustainable Use of Tropical and Sub-tropical Wetlands* (Paris, France: OECD, 1996).

Table 23: Summary of Canada's Boreal Wetland Ecosystem Service Values (Current Estimated Value of Conserving Natural Capital in Canada's Boreal Region)

Type of Good or Service	Total Area (hectares)	Total Value (billions, 2002$)	Value per Hectare (2002$)
Non-peatland wetland ecosystem values (flood control, water filtering, and biodiversity)	2,836,800	3.4/year	1,189/year
Peatland carbon storage value	83,199,800	349.1	4,196
Peatland carbon sequestration value	83,199,800	0.4/year	4.6/year
Peatland flood control and water filtering services	83,199,800	77.0/year	926/year
Total	86,036,600 (total wetland area)	349.1 for peatland carbon storage plus 80.6/year in annual benefits	4,196 for peatland carbon storage plus 2,119/year in annual benefits

Source: See above sections for sources used to estimate values for peatlands and non-peatland wetland values.

and recreational property development.[145] The group also reports that boreal wetlands have been affected primarily by conversion to hydroelectric power reservoirs and corridors, peat extraction for agriculture and energy, and forestry harvesting.

4.2.3.5.3 *Total Boreal Wetland Ecosystem Service Values—Summary*

The total boreal wetland ecosystem service values are $349 billion for carbon storage plus $80.4 billion per year in other services. The total value per hectare is $4,195 for peatland carbon storage plus $2,119 per year for all wetland areas (see Table 23).

4.2.3.6 The Value of Nature—Based Recreation in Canada's Boreal Region

Recreation and tourism are two of the fastest growing economic sectors. In the United States, the Forest Service has valued recreational activities in national forests as contributing $110 billion annually to the GDP.[146] In addition, studies have shown that wild, roadless lands in the United States offer unique recreational opportunities, and based on an average value of $41.87 per visitor day, the economic value of recreation on the 42 million acres of roadless areas in US national forests totals $600 million annually.[147]

In Canada, the most current information available on nature-related activities is Environment Canada's 1996 *Survey on the Importance of Nature to Canadians*. This survey includes outdoor activities in natural areas, wildlife viewing, recreational fishing, hunting, residential wildlife-related activities, and indirect nature-related activities. According to the 1996 survey, 20 million Canadian residents took part in nature-related activities in Canada in 1996.[148] The survey also found that Canadians took a total of 160 million nature-related trips in 1996. In all, 47.4 million (30 percent) of these trips were within or to the boreal region, with the greatest number of trips taken to the Boreal Shield and Boreal Plains ecozones. In total, participants in the survey reported spending 1.6 billion days on nature-related activities in 1996; 193 million days alone were spent on nature-related activities in the

145 National Wetland Working Group (NWWG). *Wetlands of Canada*. Ecological Land Classification Series, No. 24. (Ottawa and Montreal: Sustainable Development Branch, Environment Canada, and Polyscience Publications, 1988).

146 Kreiger, *The Economic of Forest Ecosystem Services.*

147 Ibid.

148 E. Duwors, M. Villeneuve, F. L. Filion, D. Burke, M. Hamel, and J. Coull. *The Importance of Nature to Canadians: A Statistical Compendium for Ecozones and Ecozones within Province or Territory in 1996*, Special Report #15 (Ottawa: Environmental Economics Branch, Economic and Regulatory Affairs Directorate, Environment Canada, 1999).

Boreal Shield ecozone, with an overall total of 245 million days spent in Boreal ecozones.

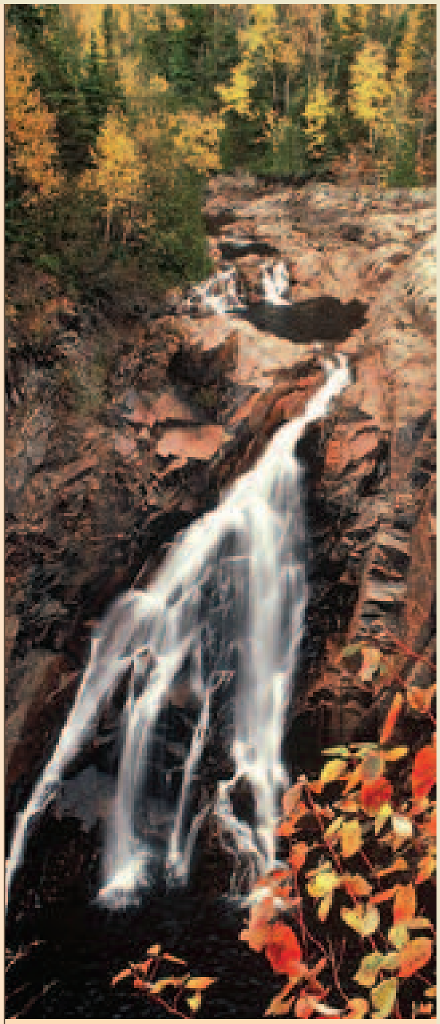
The 1996 survey also addressed expenditures on nature-related activities and their economic impacts. According to the survey, 20 million Canadians spent $11.0 billion in Canada during the year to pursue nature-related activities.[149] These expenditures included $1.3 billion for wildlife viewing, $1.9 billion for recreational fishing, over $800 million for hunting, and $1.2 billion for other nature-related activities such as contributions to nature-related organizations, sustaining land for conservation, and residential wildlife-related activities.[150] Canadians spent over $7.2 billion of the total expenditures on outdoor activities in natural areas in Canada, with the average participant spending $704 over the year or $44 per day of participation. In addition, US visitors spent over $700 million on wildlife viewing and recreational fishing in Canada.[151]

Nature-related activities also have an impact on national, provincial, and territorial economies. According to the same survey, the $11.7 billion (i.e., Canadian plus US visitor expenditures on nature-related activities; $12.8 billion in 2002$) spent on such activities generated $17.3 billion ($18.9 billion in 2002$) to gross business production and $12.1 billion ($13.2 billion in 2002$) to Canada's GDP. These expenditures also led to contributions of $5.9 billion ($6.4 billion in 2002$) in personal income, 215,000 jobs, and $5.4 billion ($5.9 billion in 2002$) in government revenue from taxes.[152]
Based on the survey's results, approximately 30 percent of total participants undertook trips in the boreal region (6.1 million), and 30 percent of total trips were undertaken in the boreal region. Therefore, we estimate that $3.8 billion (2002$) of the total expenditures would have been spent on nature-related activities in the boreal region. Using the dollar generated per dollar spent from the survey's input/output model results, the impact of the boreal region expenditures would have the following estimated economic impact on Canada's economy: $5.7 billion on gross business production, $4.0 billion on GDP, $1.8 billion in government revenue from taxes, and $1.9 billion in personal income generated by 64,500 sustained jobs (2002$).

The above expenditures reflect the actual spending by Canadians on nature-related activities in the boreal region. In addition, participants were asked to report the amount by which their costs would have had to increase in order to not participate in these activities. This question was asked to estimate the economic value or marginal value of nature-related activities in Canada. The survey revealed that Canadians placed a significant economic value on such activities and, in 1996, were willing to pay an additional $2 billion ($2.2 billion in 2002$) for nature-related activities. Based on 30.2 percent of participants reporting the boreal region as their destination, we estimate that the marginal value of nature-related activities in the boreal region is $654.7 million per year (2002$).

Therefore, a total of $4.5 billion per year (2002$) is the estimated value of nature-related activities in the boreal region.

149 Survey included 10 provinces and the Yukon. It excluded the Northwest Territories due to its vast size and sparse population, which made it prohibitively expensive to reach its population for survey.
150 Environment Canada. *The Importance of Nature to Canadians: The Economic Significance of Nature-Related Activities* (Ottawa: Minister of Public Works and Government Services Canada, 2000).
151 The total spent by US visitors would be higher if it included spending for other nature-related activities such as camping, sightseeing, boating, and hiking.
152 Environment Canada. 2000. *The Importance of Nature to Canadians.*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The Value of Nature-based Recreation

Recreation and tourism are two of the fastest growing economic sectors.

In the United States, the forest service has valued recreational activities in national forests as contributing $110 billion annually to the GDP.

In Canada, according to Environment Canada's "Survey on the Importance of Nature to Canadians", 20 million Canadians spent $11.0 billion in Canada during 1996 on nature-related activities.

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5.

CONCLUSIONS

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The primary purpose of our two-year study is to begin to identify, inventory, and measure the full economic value of the many ecological goods and services provided by Canada's vast boreal region. For this purpose, we developed the Boreal Ecosystem Wealth Accounting System (BEWAS), a tool for measuring and reporting on the physical conditions and the full economic value of the boreal region's natural capital and ecosystem services.

The study reveals the broad range of ecological goods and services provided by Canada's boreal region. These have been organized into a BEWAS. The purpose of the BEWAS is to give Canadian decision makers a boreal natural capital "balance sheet" for assessing the sustainability, integrity, and full economic value of the boreal region. We have identified a number of functions of ecosystem services: atmospheric stabilization; climate stabilization; disturbance avoidance; water stabilization; water supply; erosion control and sediment retention; soil formation; nutrient cycling; waste treatment; pollination; biological control; habitat; raw materials; genetic resources; and recreation and cultural. As noted, most of these ecosystem services go unaccounted for in conventional economic decision making.

The second result of this study is that it begins to estimate some of the economic value of the boreal region's many ecological goods and services using the BEWAS as an analytic and reporting framework. The purpose of such valuation work is to provide decision makers with a means of considering the full economic value of the many ecosystem services of the boreal region when making decisions about its future.

The results of the preliminary economic valuation estimates of the boreal region are summarized in Table 24. We have estimated the ***annual*** market values of natural capital extraction and the non-market values of ecosystem services in the boreal region for the year 2002. The market values associated with the use of some of the boreal region's natural capital resources (e.g., timber, minerals, water) are calculated based on estimates of the contribution their extraction makes to Canada's GDP, adjusted for some of the regrettable environmental and societal costs associated with natural resource extraction. The estimated **net market value of boreal natural capital extraction in 2002 is $37.8 billion.** If accounted for, boreal natural capital extraction would equate to 4.2 percent of the value of Canada's GDP in 2002. The net market value calculation is based on the contribution to Canada's GDP from boreal timber harvesting; mineral, oil, and gas extraction; and hydroelectric generation ($48.9 billion; or $83.63 per hectare of the boreal ecosystem land base) minus the estimated **$11.1 billion in environmental costs (e.g., air pollution costs) and societal costs (e.g., government subsidies)** associated with these industrial activities.

We have also estimated the non-market values of a small subset of boreal ecosystem services, including the economic value of carbon sequestration by forests and peatlands, nature-related recreation, biodiversity, water supply, water regulation, pest control, non-timber forest products, and Aboriginal subsistence values. The estimated **total non-market value of boreal ecosystem services in 2002 is $93.2 billion** (or $159.52 per hectare of the boreal ecosystem land base). If accounted for, boreal ecosystem services would equate to 8.1 percent of the value of Canada's GDP in 2002. The ecosystem services with the highest economic value per year are (1) flood control and water filtering by peatlands—$77 billion; (2) pest control services by birds in the boreal forests—$5.4 billion; (3) nature-related activities-$4.5 billion; (4) flood control, water filtering, and biodiversity value by non-peatland wetlands—$3.4 billion; and (5) net carbon sequestration by the boreal forests-$1.85 billion.

When we compare the market and non-market values for 2002, **the total non-market value of boreal ecosystem services is 2.5 times greater than the net market value of boreal natural capital extraction.** This result is significant. It suggests that the ecological and socio-economic benefits of boreal ecosystem services, in their current state, may be significantly greater than the market values derived from current industrial development-forestry, mining, and hydroelectric energy—combined.

What does this mean? It affirms the relative importance of ecosystem functions that have no markets in which their services are traded, and the potential cost of replacement if human-made infrastructure can replace their services. It is important to note that the estimates in this study do not reflect the total cost of replacement and that in most cases, it is not possible to replace whole ecosystems. However, the estimates of ecosystem economic values provide a base value for improved decision making. For example, in many cases, it is clear that it will be more costly to restore ecosystem functions than it is to conserve them.

Table 24: Summary of Natural Capital Economic Values for Canada's Boreal Region

Boreal Ecosystem Wealth *Natural Capital* Accounts	Monetary Economic Values and Regrettable Costs[a] (2002$ per annum)[b]
Forests	**Market values:** • $14.9 billion in estimated market value of forestry-related GDP in the boreal region (est. 2002) **Costs:** • $150 million in estimated cost of carbon emissions from forest industry activity in the boreal region (deduction against forestry-related GDP) **Non-market values:** • $5.4 billion in value for pest control services by birds • $4.5 billion for nature-related activities • $1.85 billion for annual net carbon sequestration (excludes peatlands) • $575 million in subsistence value for Aboriginal peoples • $79 million in non-timber forest products • $18 million for watershed service (i.e., municipal water use) • $12 million for passive conservation value
Wetlands and peatlands	**Non-market values:** • $77.0 billion for flood control and water filtering by peatlands only • $3.4 billion for flood control, water filtering, and biodiversity value by non-peatland wetlands • $383 million for estimated annual replacement cost value of peatlands sequestering carbon
Minerals and subsoil assets	**Market values:** • $14.5 billion in GDP from mining, and oil and gas industrial activities in the boreal region (est. 2002) **Costs:** • $541 million in federal government expenditures as estimated subsidies to oil and gas sector in the boreal region • $474 million in government expenditures as estimated subsidies to mining sector in the boreal region
Water resources	**Market values:** • $19.5 billion in GDP for hydroelectric generation from dams and reservoirs in the Boreal Shield ecozone (est. 2002)

TABLE 24: SUMMARY OF NATURAL CAPITAL ECONOMIC VALUES FOR CANADA'S BOREAL REGION

Boreal Ecosystem Wealth Natural Capital Accounts	Monetary Economic Values and Regrettable Costs[a] (2002$ per annum)[b]
Waste production (emissions to air, land, and water)	Costs: • $9.9 billion in estimated air pollution costs to human health[c]
TOTAL market values (forestry, mining, oil and gas industrial activity, and hydroelectric generation)	$48.9 billion
Less cost of pollution and subsidies: • Air pollution costs • Government subsidies to mining sector • Federal government subsidies to oil and gas sector • Forest sector carbon emission costs	 - $9.9 billion - $474 million - $541 million - $150 million
NET market value of boreal natural capital extraction	$37.8 billion
TOTAL non-market value of boreal ecosystem services	$93.2 billion
RATIO of non-market to market values	2.5

Note: Market values are shown in blue; non-market values are shown in green; and environmental/societal costs are shown in red.

a These are either environmental or societal costs associated with market-based activities (e.g., forest industry operations).

b A GDP chained, implicit price index was used throughout the study to standardize to 2002 dollars.

c Based on European Union air pollution cost estimates for SO_2, NO_x, $PM_{2.5}$, and VOC for 2002.

HIGHLIGHTS OF RESULTS

The following are the key highlights of our study and analysis.

The results of the estimated **net market value of boreal natural capital extraction** for 2002 include:

- Canada's boreal forests contributed an estimated $14.9 billion to Canada's GDP from harvested timber (based on estimates that 60 percent of Canada's forest industry activity occurs in the boreal region).
- Mining, and oil and gas industrial activities in the boreal region contributed an estimated $14.5 billion to Canada's GDP.
- Hydroelectric generation from dams and reservoirs in the Boreal Shield ecozone contributed an estimated $19.5 billion to Canada's GDP.
- There is an estimated $11.1 billion in air pollution and government subsidy costs associated with forestry and mining sector activities; costs that should, in principle, be deducted from the market GDP value as environmental and social costs of development.

The results of the estimated **total non-market value of boreal ecosystem services** for 2002 include:

Forests

- The *annual* non-market boreal forest ecosystem service values are estimated at $12.4 billion, or $51.24 per hectare per year for 2002; this figure includes an estimated $1.85 billion for the *annual* net carbon sequestration by forests.
- Like a bank account, Canada's boreal forests and peatlands represent a massive storehouse of carbon. An estimated 67 billion tonnes of carbon are stored in the boreal region—the equivalent of 303 years of Canada's total 2002 carbon emissions, or 7.8 years of the world's total carbon emissions in the year 2000. How much is this stored carbon worth to the world? Munich Re, one of the world's largest reinsurance companies, has estimated that the cost to the global insurance industry of continued increases in global carbon emissions to the atmosphere could reach US$304 billion per year by the end of the decade. Using this estimate as a proxy for the value of maintaining carbon storehouses like the boreal region would suggest a value of carbon at US$46 per tonne of carbon (based on total global carbon emissions in the year 2000). Using Munich Re's carbon value estimates would place the value of the current total carbon stored in Canada's boreal "carbon bank account" at US$3.7 trillion.

Wetlands and Peatlands

- The annual non-market boreal wetland and peatland ecosystem service values (flood control, water filtering and biodiversity value) are estimated at $80.4 billion ($934 per hectare of wetland and peatland combined per year), plus $383 million per year for carbon sequestration by peatlands. In terms of stock values, 83.2 million hectares of peatland in Canada's boreal region hold an estimated 19.5 billion tonnes of carbon worth an estimated $349 billion (i.e., carbon stock value; $4,195 per hectare).

Nature-based Recreation

- Approximately 6.1 million Canadians participate in nature-related activities per year in Canada's boreal region worth an estimated $4.5 billion ($3.8 billion in total nature-related-activity expenditures plus $654.7 million per year in economic value; included in annual forest ecosystem total value).
- Based on input/output modelling, the above boreal region expenditures would have the following economic impact on Canada's economy: $5.7 billion on gross business production, $4.0 billion on GDP, $1.8 billion in government taxes and revenue, and $1.9 billion in personal income generated by 64,500 sustained jobs.
- While our account of the boreal region is preliminary, it reveals the importance of measuring the full range of ecological and social values of ecosystems to Canadians. The accounts also begin to show that the increasing pressures on boreal ecosystem integrity from human and industrial development could potentially threaten the future economic well-being of Canadians and global citizens.

We consider our estimates to of ecosystem service values to be both incomplete and conservative. While incomplete, they demonstrate the importance of conserving the fullest possible range of ecosystem services for the benefit of both Canadians and global citizens vis-à-vis the important market values derived from natural capital extraction. Indeed, the true value of the boreal region in its most integral state might be best appreciated by those nations whose ecosystems have already been irreparably degraded or destroyed.

The results of our study suggest that Canadians have important issues to contemplate, namely:

- What level of development would be acceptable in order to minimize further fragmentation, loss of intact boreal ecosystems, and the degree of damage to ecosystem function?
- How much of the current intact boreal ecosystems should be protected from future development?
- What are the real economic costs and benefits to Canadians if industrial development of the boreal region is forgone?
- What is the true value of conserving the integrity and full functional capacity of the boreal region's ecosystems for current and future generations of Canadians and global citizens?

- Are other nations willing to pay Canada for preserving the boreal region's ecological goods and services?
- Should Canada adopt a more precautionary and conservative approach to decision making with respect to the boreal region by ensuring ecosystem integrity and optimum ecosystem service capacity are the primary objectives of future land-use planning and development?

In order to answer these questions and make well-informed decisions, all levels of government (federal, provincial, and municipal), working with industry and local communities, need to make a commitment to:

- Develop a system of natural capital accounting, such as the BEWAS, to guide land-use planning, resource management, and economic development policies. This accounting system would include a comprehensive and nationally coordinated inventory of boreal natural capital;
- Incorporate accounts of natural capital and ecological goods and services in national and provincial income accounts to guide economic, fiscal, and monetary policies, and;
- Provide full cost accounting of social and environmental costs associated with natural capital development (through extraction) and total economic valuation of natural capital and ecosystem services.

The primary shortcoming of our BEWAS estimates for 2002 is the lack of data on both natural capital resources and the condition of ecosystem services and functions. In attempting to construct a preliminary BEWAS, we conducted an exhaustive search of numerous government and other datasets on natural capital related to the boreal region that could be used to "populate" our BEWAS framework with real current and historical data. It became evident that there is a significant deficit in basic natural resource inventory information. For example, stock data on boreal natural capital assets such as forest inventory, minerals, petroleum resources, water resources, fish and wildlife, and arable agricultural land are either not available or wanting. Moreover, flow data such as the volume and rate of timber harvesting, the impact on forests of other land-use development (e.g., oil and gas development), and the impact of forest fires on boreal forests are not available. Our attempts to develop a boreal carbon account (the amount of carbon stored and sequestered annually) based on Canada's National Forest Inventory (CanFI) were hampered by a lack of sufficient progress on, and utility of, Canada's emerging carbon budgeting model. Most importantly, there is simply no information on or measures of the integrity of boreal ecosystems, and thus no capacity for assessing the condition of ecosystem services. In the absence of hard, quantitative inventory data, we faced a daunting challenge in constructing a meaningful set of economic value estimates for the boreal region's natural capital and ecosystem services.

Our study's results appear to be conservative. One of the first attempts to measure the value of ecosystem services globally was undertaken by Robert Costanza and a team of ecologists and economists in 1997. Costanza et al. estimated the total economic value (TEV) of the world's ecosystem services.[153] Based on a study of 17 ecosystem service valuation studies for 16 biomes, they estimated the non-market value of Earth's ecosystems between US$16 and US$54 trillion per year, or an average value of US$33 trillion per year. The authors suggested their estimates were conservative if not a minimum value. Costanza et al. estimated total ecosystem service values for the temperate forest biome to be worth $467.08 per hectare per year (2002$Cdn).[154] If we were to apply Costanza et al.'s per hectare ecosystem service value estimate to Canada's entire boreal region (584 million hectares), then the estimated total value of Canada's boreal ecosystem services would equate to $244.7 billion per year, or over two times our estimate of $93.2 billion per year (i.e., $159.52 per hectare per year [2002$Cdn]). The discrepancy between our estimate and Costanza et al. estimates is likely due to the fact that their study attempted to measure a greater number of ecosystem services.

While the Costanza et al. study has remained provocative, providing ecosystem service values that are commonly quoted, it has also been criticized.[155] One of the criticisms involves the type of valuation methodology. It has been argued that valuation of ecosystem services should assess the marginal value of ecosystem service losses; that is, valuation should measure the marginal or additional unit value of the opportunity cost to the

153 Costanza et al., "The Value of the World's Ecosystem Services and Natural Capital."

154 The Costanza et al. figures were converted to Cdn dollar equivalents by Mark Anielski and Sara Wilson (Anielski and Wilson, *The Alberta GPI Accounts*).

155 One of the shortcomings of the Costanza et al. (1997) and Balmford et al. (2002) work is the lack of transparency in methodology and assumptions. While the authors point to supplemental information that provides greater details of the studies they used in their synthesis workshop, we were unable to locate this material. Notwithstanding these criticisms, Costanza et al.'s work provides at least one set of proxies for a series of ecosystem service values.

economy of losing an additional area of intact ecosystem or losing ecosystem functionality. In 2002, Balmford et al. followed up Costanza et al.'s 1997 study by estimating the cost of habitat degradation to the world's economy ($250 billion each year).[156] Using the opportunity costs compiled in their study, the authors estimated that developing a network of global nature reserves would ensure the delivery of goods and services worth at least $400 trillion more each year than the goods and services from their converted counterparts. Their results suggest that the economic value of keeping ecosystems wild far outweighs the value of converting these areas to cropland, housing, or other human uses. The authors concluded that the benefit-to-cost ratio is more than 100 to 1 in favour of conservation—a "strikingly good investment." The net opportunity value of ecosystem services at the margin was based, in part, on the 1997 work of Costanza et al. on gross ecosystem service benefits, adjusted to reflect net benefits at the margin of ecosystem service losses.[157]

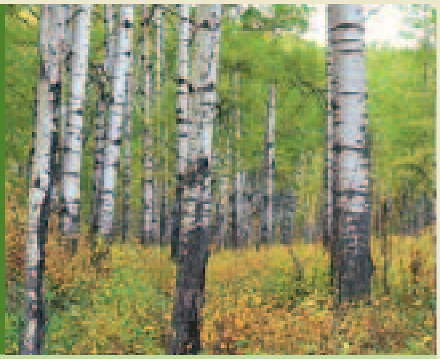
But are there limits to placing a price on ecosystems? There is no question that in our present economy, where monetary valuation creates dollar metrics that facilitate trade-off decisions, estimating the economic values of natural capital and ecosystem services is useful. However, there are limits to the use of economic valuation. Ecological economist Tom Green argues that in a society truly committed to the goals of sustainability, valuation would be unnecessary (i.e., a sustainable scale of economy is determined vis-à-vis the capacity of ecosystems).[158] Once this scale has been set, protected areas, regulations, quotas, and other instruments would adjust the economy to its defined limits. However, our society is not yet at this stage and, therefore, tools such as valuation are helpful to encourage the leap to a sustainable scale. Ecosystem valuation is a technique that will help integrate the importance of ecosystems into policy and land-use decision-making. As of yet, ecosystems are not well represented.

The premise of our study is that an accounting system like BEWAS is needed to inform and guide wise decision-making. Ecosystem valuation and ecosystem accounts are tools that can help communities, planners, economists, and other decision makers make the connection between society's needs and the goods and services that flow from ecosystems. These tools can also capture the attention of such people who are making decisions at the local level, in terms that are relative to the status quo. However, at the same time, it is important to understand the limitations of ecosystem valuation. Economic valuation does not fully represent the values of ecosystems and, therefore, should not be the only tool used in decision making. Ecological, cultural, and social values associated with the sustainability of ecosystems need to be considered in policy decisions, including the existence value of non-harvested wildlife species or the spiritual and aesthetic value of natural, undisturbed ecosystems to both indigenous and non-indigenous people. As a result, ecosystem accounts based on comprehensive ecological inventories, data analysis, and spatial analysis, at all jurisdiction levels, are needed with input from ecologists, natural scientists, local representatives, and economists.


Garth Lenz

156 Andrew Balmford, Aaron Bruner, Philip Cooper, Robert Costanza, Stephen Farber, Rhys E. Green, Martin Jenkins, Paul Jefferiss, Valma Jessamy, Joah Madden, Kat Munro, Norman Myers, Shahid Naeem, Jouni Paavola, Matthew Rayment, Sergio Rosendo, Joan Roughgarden, Kate Trumper, and R. Kerry Turner. "Economic Reasons for Conserving Wild Nature," *Science* 297 (August 9, 2002): pp. 950-953.
157 Based on a personal conversation with Dr. Robert Costanza, September 6, 2002.
158 As per email communication with Tom Green, May 17, 2005.

6. RECOMMENDATIONS



Garth Lenz

1. Given the absence of a complete inventory of the stocks and consumption of timber, minerals, carbon, wetlands, marine resources, wildlife, and fisheries in the boreal region, we recommend that a comprehensive inventory of the area be completed and made publicly available. National, provincial, and local boreal region accounts should be developed including physical stock and flow accounts (inventory) of natural capital assets and ecosystem services. These accounts should include information on the following: annual average growth rate of timber; fires (in terms of both area and volume lost); insect infestation; carbon sequestration by forests and wetlands; fisheries; and annual water flow rates in rivers and groundwater aquifers. Finally, these accounts should include an account of the state of ecosystem services in order to track or measure changes in ecosystem functionality and their respective service values.

2. We recommend that the specific effects of each type of human disturbance be identified, tracked, and monitored to determine the change in economic value of the boreal region's ecosystem services.

3. We recommend that economic values for ecosystem services be further developed and adopted by all jurisdictions for resource and land-use planning, especially at the municipal and provincial levels where changes in land-use and resource planning are made.

4. Our analysis found that the total non-market value of boreal ecosystem services is 2.5 times greater than the net market value of boreal natural capital extraction. This result indicates that an economic argument exists that supports a significant expansion of the network of protected areas in the boreal region, consistent with the Boreal Forest Conservation Framework's vision for sustaining the integrity of the region. We recommend that a policy be developed to expand the network of protected areas in the boreal region that would serve as an investment in the natural capital of the boreal region for the benefit of current and future generations of Canadians and global citizens.

5. We recommend that in order to ensure the optimum value of ecosystem services is recognized and conserved, resource management and land-use decisions need to account for impacts (i.e., costs and benefits) on ecosystem services and the overall state of the region's natural capital. The Boreal Forest Conservation Framework's vision of conservation-based resource management practices should be implemented in order to minimize costs and maximize local ecological values.

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Appendix I: Towards an Accounting of Boreal Ecosystem Integrity

While our study provides a framework for measuring numerous natural capital attributes and ecosystem functions, it does not provide an accounting of the integrity of the boreal as an ecosystem. To have integrity means to be whole or complete. So what is the state of integrity of Canada's vast boreal region? Moreover, what are the consequences of ecosystems whose integrity has been damaged or degraded, where some of its ecological functions have been damaged due to human and industrial development?

The answers to these questions are complex. However, the ultimate goal of such boreal natural capital and ecosystem service accounting is to assist decision makers in making that kind of integrity diagnosis. Just like measuring the integrity or overall health of our bodies, assessing the integrity of Canada's boreal region as an ecosystem should be the ultimate next step forward.

Just as with human health, there is certainly value in having full integrity of ecosystems. On the other hand, where integrity has been lost, there is usually a cost associated with remediation of the damage, which in hindsight may be regrettably costly in terms of replacement infrastructure.

Just as we need a medical checkup to understand the state of our health, so too do ecosystems need a checkup to understand and track their overall health and well-being. Such an assessment should include estimates of the economic values of their numerous ecological functions, goods, and services and their estimated depreciation costs through full cost accounting. By providing an account of the physical condition of the boreal region and its ecosystem services, Canadians can assess the potential regrettable and irreversible losses in ecological goods and services in land use and resource decisions.

But how should we account for ecological integrity? What measures or indicators can we use to diagnose the well-being of a system as complex as a wetland? Is it possible to directly measure the physical state or condition of the many ecosystem services we have identified?

As complicated as it is to measure human health or well-being, measuring the integrity or well-being of ecosystems presents a greater challenge. First, natural ecosystems are poorly understood, and second, even less information is compiled to track the extent of each system and the well-being of its components. One way to assess integrity is through ecological indicators, or proxies of integrity. For example, the diversity of key species of plants, birds, and mammals in a wetland, and their respective population, may tell us something about the overall health of the ecosystem. Indicators could be developed that measure the "condition" of all three dimensions of an ecosystem, akin to a 50-point health checkup. The ultimate goal is to assess the biological condition or ecological performance of the ecosystem as a living and whole system.

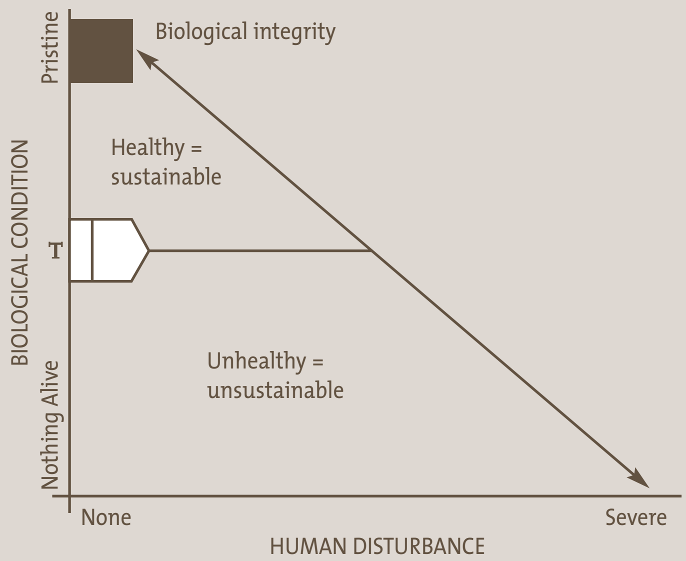
Aquatic ecologist Dr. James Karr[159] has developed what he calls the Index for Biological Integrity (IBI) to measure the well-being, or integrity, of aquatic systems (e.g., rivers, streams, and riparian zones). The IBI measures biological or ecological integrity by the diversity, number, and overall health of species in an aquatic ecosystem. Karr has shown that ecological integrity, as measured by the IBI, declines with increasing human disturbance. Figure 5 illustrates this relationship. Karr describes biological integrity as the condition of a place that has its evolutionary legacy—its parts (e.g., species) and processes (e.g., nutrient cycles)—intact. Degradation of the biological condition beyond a threshold (in the vicinity of T, an

159 J. Karr. "Health, Integrity, and Biological Assessment: The Importance of Measuring Whole Things," in *Ecological Integrity: Integrating Environment, Conservation and Health*, ed. D. Pimentel, L. Westra, and R. Noss (Washington, DC: Island Press, 2000), pp. 209-226.

ecological "tipping point") is where an ecosystem becomes unhealthy because its functionality has become compromised or unsustainable. Karr notes that T is a tipping point beyond which neither the natural biota nor human activity can be sustained in that place, though T is not easily defined or measurable over short time periods. Karr's model considers the ideal, or "pristine," biological condition as a biota that is a balanced, integrated, adaptive system with a full range of elements (i.e., genes, species, and assemblages) and processes (i.e., mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation processes) that are expected in areas with minimal human influence.

What is useful about Karr's IBI is that it looks at the relationship between **human pressures** on ecosystems and **ecosystem integrity** by examining the well-being of non-human species, as a rough proxy, without directly measuring ecosystem functions. One of the challenges in large terrestrial ecosystems like the boreal region is taking inventory of the complexity of species that make up the various types of ecosystems from forests to wetlands. Some scientists, including University of Alberta's Dr. Stan Boutin, have just begun to work on creating similar IBI estimates for terrestrial boreal ecosystems. Boutin and other scientists are examining the utility of examining the state of key indicator species of insects, birds, and other mammals as indicators of ecological integrity. Because this work is in its infancy, it will be several years before a useful accounting of boreal integrity using species and indices like the IBI will be available to decision makers. The bottom line is that we lack the species inventory to provide a useful integrity analysis of the "state" of boreal ecological integrity.

Figure 5: Biological Integrity Continuum



Source: Karr, J. 200. Health, Integrity, and Biological Assessment: The Importance of Measuring Whole Things. Pp. 209-226 in D. Pimentel, L. Westra and R. Noss. eds., *Ecological Integrity: Integrating Environment, Conservation and Health*. Island Press, Washington. DC.

Despite this shortcoming, Karr's IBI framework does provide another possible methodological approach to assessing the state of ecosystem integrity. Namely, the trends in human disturbance pressures (e.g., resource extraction, ecosystem fragmentation from linear disturbance, pollution, and emissions) can be tracked and mapped to show where ecological integrity is under the greatest threat.

The Pressure-State-Response model provides a useful accounting framework for assessing ecological integrity (see Figure 6). Using this framework, it is possible to account for the various kinds of human and industrial pressures (i.e., the ecological footprint) that human enterprise is placing on ecosystems. These pressures include industrial development, community development, and other human pressures on natural systems. We know that these pressures, including natural disturbance pressures (e.g., fire), affect the state or condition of the wholeness or integrity of an ecosystem. However, natural disturbance is part of the natural ecosystem and can be seen as one of nature's services; so it should not necessarily be seen as a negative occurrence or regrettable pressure. In fact, such an occurrence is part of the renewal of an ecosystem and a necessary disturbance for the regeneration of some boreal species.

How we respond to a change in the state of an ecosystem constitutes the human response in the form of changes to policies either regarding land use or resource management.

It may be sufficient, even in the absence of complete information of the state of ecological integrity or knowledge of the proximity to an ecological "tipping point," to account for the scale and degree of industrial development as a basis of applying the precautionary principle in order to avoid the potential irreversible loss or degradation of ecosystems and their functions.

Karr argues that at the very least the observed biota of minimally disturbed sites provide benchmarks or a standard against which other sites of similar biological characteristics under varying degrees of human disturbance, impacts, or pressures can be compared.[160] This would require a common and routine biological assessment of the condition or biota of a continuum of sites to provide information about whether we are going in the right direction of ecosystem health and sustainability and at what rate (relative to a benchmark of "pristine" or undisturbed conditions).

Karr says the challenge is that ecosystems are not static; they are in a state of constant flux responding to various influencers that affect their health or integrity. Ecosystems are fundamentally resilient but tend to exhibit random or chaotic bifurcations over time.

Figure 6: Pressure-State-Response Model

160 Ibid.

Appendix II: Pressures on Canada's Boreal Ecosystems

The ecosystem values presented in our study assume that boreal ecosystems are fully functional. In other words, benefit values are applied to the total ecosystem area and due to a lack of data, no adjustments are made for the effects of land use. Therefore, it is important to also develop tools that can evaluate the integrity or functional abilities of ecosystems across Canada, including the boreal region.

Maintaining and restoring, where necessary, the integrity or health of boreal ecosystems—with their multitude of life-support functions—is critical to the sustained health of our environment and the economy. The global boreal region represents 25 percent of the world's remaining intact forests, and the Canadian boreal region is one of the last places left on Earth that is sufficiently intact to maintain fully functioning ecosystems.

The following analysis compiles and illustrates some of the development currently placing pressures on Canada's boreal ecosystems. Spatial analysis is used as a tool to begin developing an account of the pressures on the boreal region's integrity, and this account can be expanded as more data become available and tracked over time.

1. Fragmentation Due to Human Disturbance in the Boreal Region

Industrial development pressure in the boreal region has resulted in landscape fragmentation due to the combined impact of forestry, oil and gas, and mining activities and other linear disturbances such as roads, well sites, and pipelines. The impacts of industrial development (i.e., forestry, mining, and oil and gas, and roads) in terms of fragmentation were estimated using spatial analysis. A map of the "human footprint" on the boreal region, including cutblocks, seismic lines, well sites, pipelines, and roads, shows where the greatest industrial development pressures currently exist. Such pressures may affect the current conditions and future vitality of boreal ecosystems and the services they provide (see Figure 7).

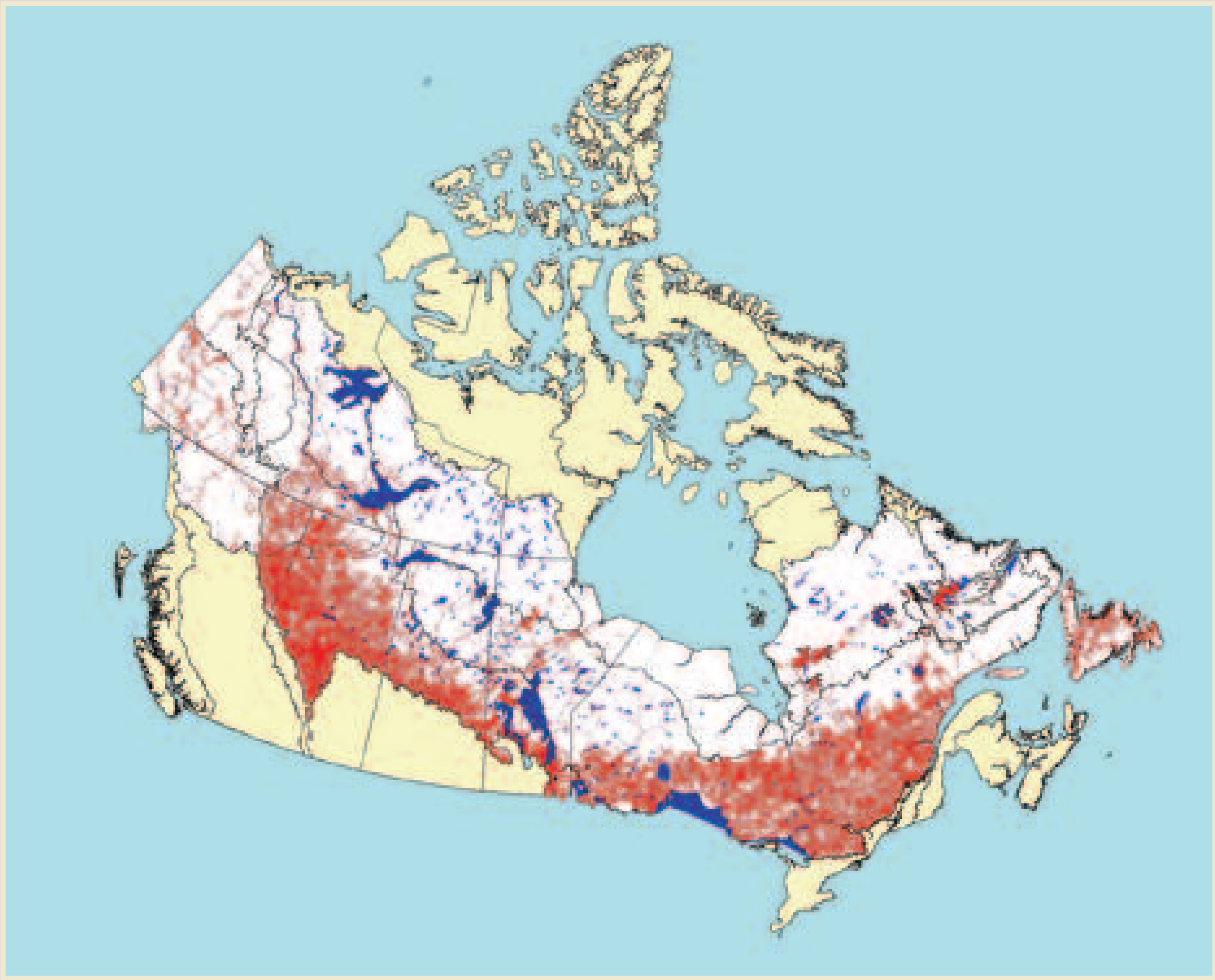
The detailed results of the spatial analysis of fragmentation in the boreal region are presented in Table 25. The total boreal area that has been fragmented by industrial and linear disturbance is 19.6 percent according to the draft analysis undertaken by Global Forest Watch Canada. The ecozone with the greatest proportion of fragmented area is the Boreal Plains ecozone (46 percent), and the ecozone least fragmented is the Hudson Plains ecozone (2 percent).

2. Natural Disturbance in the Boreal Region

In addition to timber harvest, other data that affect the stock of forest resources and the integrity of forest ecosystems were considered, including the extent and potential impacts of fire and insects. Only rough data on the estimated area of forests burned by wildfires were available. Thus, exact information on the volume of timber burned as a result of fire was not available. However, the occurrence of fire in the boreal region has increased over the past 30 years. Based on the average area burned between 1980 and 1997, an estimated 2.5 million hectares of forest burns each year, affecting 236.2 million cubic metres of timber per year. There were no data on the area of forest affected by insect infestations or the area of forest that is effectively dead due to infestations.

In terms of interpreting a natural disturbance, an approach must be taken to determine whether its impact is negative or part of the ecosystem's disturbance regime and therefore an essential service unto itself. Forest ecosystems in the boreal region are dependent on fire for regeneration. Therefore, tools such as the Range of Natural Variability (RONV) should be used to assess the impact of natural disturbances. For example, if the area burned was within the RONV for a specified ecosystem, then the disturbance would not be assessed as having a negative impact on ecosystem integrity. However, when the area disturbed by fire exceeds the RONV, the disturbance would be considered outside the natural regime. Presently, the

Figure 7: Boreal Ecosystem Fragmentation from Forestry, Mining, Oil and Gas, and Other Industrial Linear Disturbances



Sources: P. Lee, D. Akesenov, L. Laestadius, R. Noguerón, and W. Smith. *Canada's Large Intact Forest Landscapes* (Edmonton: Global Forest Watch Canada, 2003),retrieved March 28, 2005 from the Global Forest Watch Canada website http://www.globalforestwatch.ca. The information and maps are based on a DRAFT 2005 dataset prepared by Global Forest Watch Canada project *Canada's Forest Landscape Fragments*, which is mapping forest landscape fragments using a modified version of methodologies developed by Global Forest Watch Russia (see http://www.globalforestwatch.org/english/russia/maps.htm) to map large intact forest landscapes in Canada, and by the Conservation Biology Institute to map unfragmented and intact forest landscapes of Alaska (still in draft form). This analysis was performed on a draft dataset developed by Global Forest Watch Canada in 2005. The dataset is under wide review by industry, governments, environmental groups, and academics. It will likely undergo changes for publication. Therefore, this present analysis should be considered as preliminary only.

Table 25: Area and Percentage of Fragmentation in Canada's Boreal Region

Ecozone	Total Area (hectares)	Fragmented Area (hectares)	Percentage of Ecozone Fragmented
Boreal Cordillera	40,727,439	2,664,826	6.5
Boreal Plains	71,111,937	32,684,809	46.0
Boreal Shield	188,588,128	47,327,116	25.1
Hudson Plains	27,555,152	517,255	1.9
Taiga Cordillera	20,491,787	423,651	2.1
Taiga Plains	57,642,619	7,690,765	13.3
Taiga Shield	68,912,420	1,612,773	2.3
Total	475,029,482	92,921,195	19.6[a]

Source: Based on analysis completed by Global Forest Watch Canada.

a This figure represents the average percentage of the total boreal forest region which has been fragmented by linear and industrial disturbance or development.

frequency of fire has been increasing and is predicted to continue due to warmer, drier conditions brought on by climate change.

3. Mining, and Oil and Gas Industrial Footprint in the Boreal Region

Mining, and oil and gas extraction in the boreal region has an estimated industrial footprint of 46.3 million hectares, of which the majority is related to oil and gas well sites and pipelines (46.0 million hectares). The "industrial footprint" of these sectors is portrayed in Figure 8, in which the spatial area affected by oil and gas activity is illustrated in light blue.[161]

The long-term impact of mining coupled with the slow recovery rate of the boreal ecosystem make mining of great concern, particularly considering its prevalence. In terms of the potential ecological impacts of mining activity, mining is often the frontier industry that introduces roads, power developments, and infrastructure into the remote or semi-remote areas.

The significant impact of oil and gas development (i.e., currently, its industrial footprint is roughly 8 percent of the total 584 million hectare area of the boreal region) on ecological integrity and ecosystem services are still largely unknown. For example, the disruption to ecological function and the services provided by peatlands, wetlands, and watersheds due to ecosystem

161 The mining industrial footprint area of 194,853 hectares is derived by GFWC by using the federal government mines 1997 dataset; there were 104 mines in the Boreal/Taiga ecozones (5 in Taiga Shield, 3 in Boreal Cordillera, and 96 in Boreal Shield). GFWC applied a 10 kilometre buffer to accommodate an ecological zone of influence around each of these mines. The total ecological footprint of these 104 mines is 194,853 hectares. GFWC also estimated the oil and gas industry industrial footprint at 46,060,000 hectares based on well site and pipeline datasets that are used as "proxy" datasets for the land surface footprint of the PNG (petroleum and natural gas) sector. Other relevant datasets were not available, including seismic lines, most pipelines, and associated roads and power lines. To compensate for the surface disturbance caused by the missing data, a generalized 2-kilometre buffer was applied to the well site and pipeline datasets. GFWC applied the following methods: (a) well sites and pipelines were clipped for the Boreal/Taiga ecozones; (b) all well site points and pipelines were buffered by 2 kilometres (for a total of 4 kilometres); (c) all well site and pipeline polygons were merged and boundaries dissolved to create a single polygon; and (d) total area covered by the single polygon was derived. The source of data included (a) source of well sites database: a commercially available well sites dataset consisting of ~465,000 well sites for all of Canada, from 1901 to 2003-it is available for purchase from IHS Energy, http://www.ihsenergy.com/; and (b) source of pipelines database: Geogratis, vmap_0_r4-it is available for download at http://geogratis.cgdi.gc.ca/download/vmap_zero_r4/canada/.

Figure 8: Oil and Gas Industrial Footprint Area Coverage in Canada's Boreal Region, June 2003

Source: **Global Forest Watch Canada. 2005** fragmentation is not currently measured nor monitored. Therefore, the potential loss of the total economic values of boreal ecosystem services due to oil and gas activity cannot be readily measured at this time. Without an assessment of the relationship between industrial activity and ecosystem integrity and the functionality of ecosystem services, it will be difficult to assess, at the margin of change, the true effect on both ecosystem integrity and the true value of ecosystem services being lost or depreciated.

4. Fragmentation Levels of Endangered Species' Habitat Ranges in the Boreal Region

One example of the effects of fragmentation can be illustrated by interpreting the degree of habitat affected for specific species. Here, we have analyzed the fragmentation levels across the habitat range of endangered species in the boreal region. The habitat ranges of selected endangered species were clipped for the Boreal and Taiga ecozones (i.e., boreal region) using spatial analysis.[162] Each species' total habitat range area and total fragmented habitat range area within the boreal region were calculated (see Table 26). The percent of fragmented habitat range is greatest for the southern mountains woodland caribou (57.7 percent), followed by the wood bison range (39.6 percent). The least fragmented habitat range is that of the wolverine (eastern and western populations).

The degree of fragmentation of a species habitat is a good indicator for the condition of a species.[163] For example, species such as woodland caribou (*Rangifer tarandus caribou*) and walleye (*Stizostedion vitreum*) have been shown to be adversely affected by linear

Table 26: Fragmentation of Endangered Species' Habitat Ranges in the Boreal Region

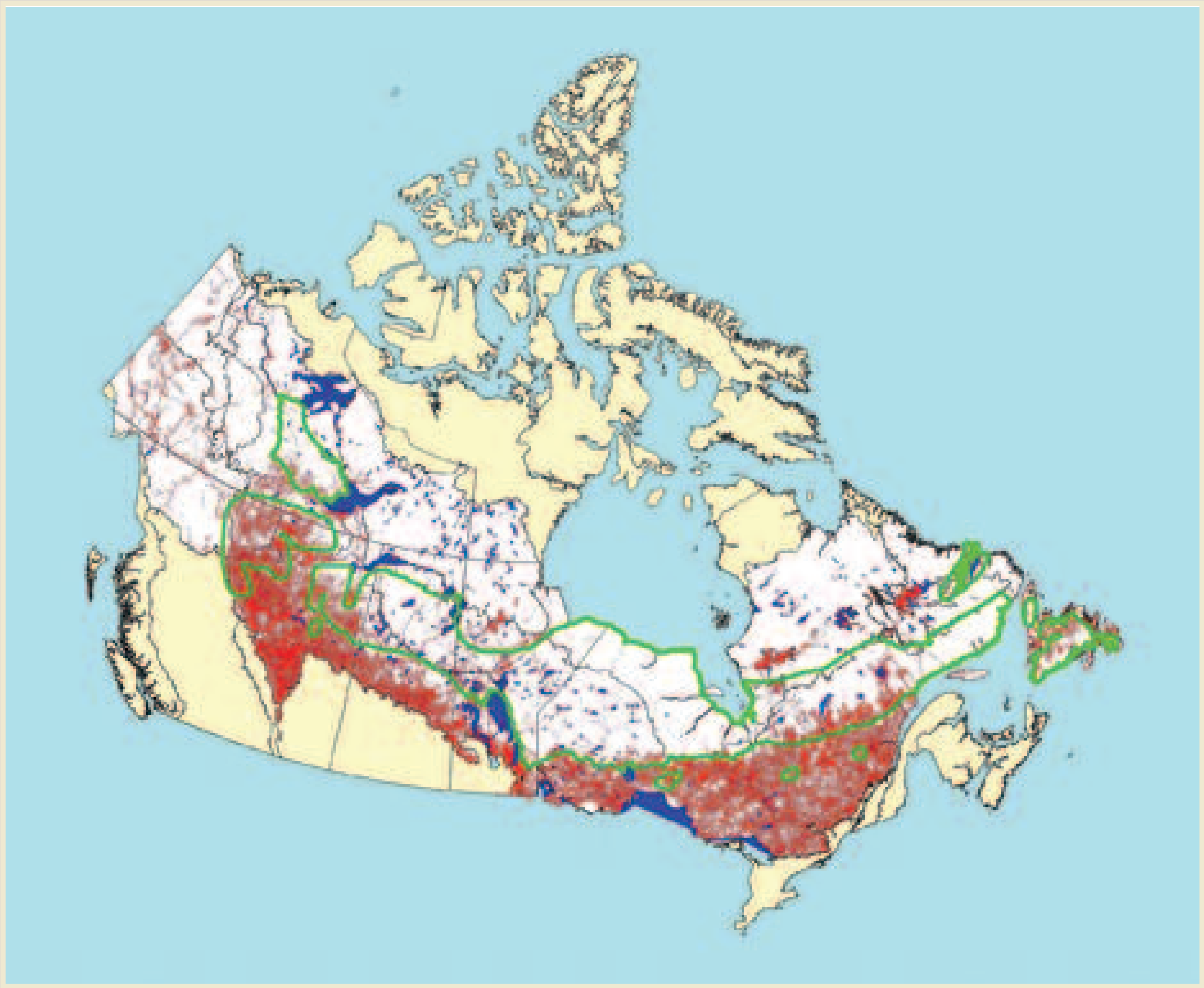
Species	Total Area of Species Habitat Range in Boreal/Taiga Ecozones (hectares)	Total Fragmented Area within Habitat Range (hectares)	Percentage of Habitat Range Fragmented
Whooping crane	249,333	13,819	5.5
Woodland caribou (southern mountains)	890,520	514,078	57.7
Woodland caribou (boreal)	178,076,964	22,614,635	12.7
Wood bison (boreal)	24,360,290	9,644,986	39.6
Wolverine (western population)	262,409,468	20,132,602	7.7
Wolverine (eastern population)	108,004,117	5,600,927	5.2
Grizzly bear	210,244,345	27,394,947	13.0

Source: Estimates made by Global Forest Watch Canada based on Environment Canada data for 2003.

162 Endangered species' ranges spatial files obtained from Environment Canada (2003 data) by Global Forest Watch Canada for the purposes of this study.

163 The work by M. Soule and J. Terborgh. *Continental Conservation: Scientific Foundations of Regional Reserve Networks* (Washington, DC: Island Press, 1999) on the issue of ecosystem connectivity notes that loss and fragmentation of habitat is the greatest risk to biodiversity. The authors provide a good discussion on the importance of maintaining ecosystem integrity, large, contiguous "megareserves" for regional conservation in core areas, corridors, networks, and buffer zones, as well as avoiding the deleterious impacts of fragmentation due to linear disturbance.

Figure 9: Boreal Fragmentation Map (Red Polygons) within Boreal Woodland Caribou Habitat (Green Line)



Source: Spatial analysis completed by Global Forest Watch Canada, 2005 disturbances and increased human access.[164] In the case of endangered species, fragmentation is an indicator of the species future viability. As fragmentation and loss of habitat increase, the viability of a species declines. Figure 9 shows the fragmented area across the boreal region with the overlay of woodland caribou habitat. The high degree of fragmentation in the western part of its habitat range is clearly illustrated. Unfortunately, there were no other data sources for other wildlife species or habitat for the boreal region. Future Boreal Ecosystem Wealth Accounting Systems (BEWAS) should include a more comprehensive analysis of fish and wildlife populations and habitat inventory.

5. Future Development of Boreal Integrity Analysis

With more comprehensive data, an overlay of several human and industrial development datasets should eventually provide an ecosystem spatial analysis or account of the cumulative impacts on boreal ecosystem health and integrity. An interpretation of our spatial analysis in terms of the status of ecological integrity and the effects on ecological function and services was not possible at this stage. However, even in the absence of precise measures of ecosystem integrity, the above fragmentation analysis reveals the spatial impact of the current landscape disturbance and fragmentation due to cutblocks, seismic lines, well sites, pipelines, and roads on boreal ecosystems. Ideally, a robust BEWAS will track and report on the changes in the condition of Canada's boreal region over time. A national commitment to more comprehensive natural capital inventories is required in order to complete a BEWAS.

6. Conclusion

The highlights of our spatial analysis of pressures on Canada's boreal region include:

- Industrial development pressure in the boreal region has resulted in approximately 20 percent of landscape fragmentation (25 percent of forest land), due to the combined impact of forestry, oil, gas, and mining activities and other linear disturbance such as roads, well sites, and pipelines.
- Mining, and oil and gas extraction in the boreal region has an estimated industrial footprint of 46.3 million hectares, of which the majority is related to oil and gas well sites and pipelines.
- The fragmented habitat range for the southern mountains woodland caribou is 57.7 percent, and for wood bison, it is 39.6 percent. Both species are endangered species in the boreal region.

164 R. R. Schneider, J. B. Stelfox, S. Boutin, and S. Wasel. 2002. "The Management of Cumulative Impacts of Land Uses in the Western Canadian Sedimentary Basin: A Case Study" (working paper, Sustainable Forest Management Network, 2002); S. J. Dyer, J. P. O'Neill, S. M. Wasel, and S. Boutin. "Avoidance of Industrial Development by Woodland Caribou," *Journal of Wildlife Management* 65 (2001): pp. 531-542; and J. R. Post and M. Sullivan. "Canada's Recreational Fisheries: The Invisible Collapse?" Fisheries 27 (2002): pp. 6-17.

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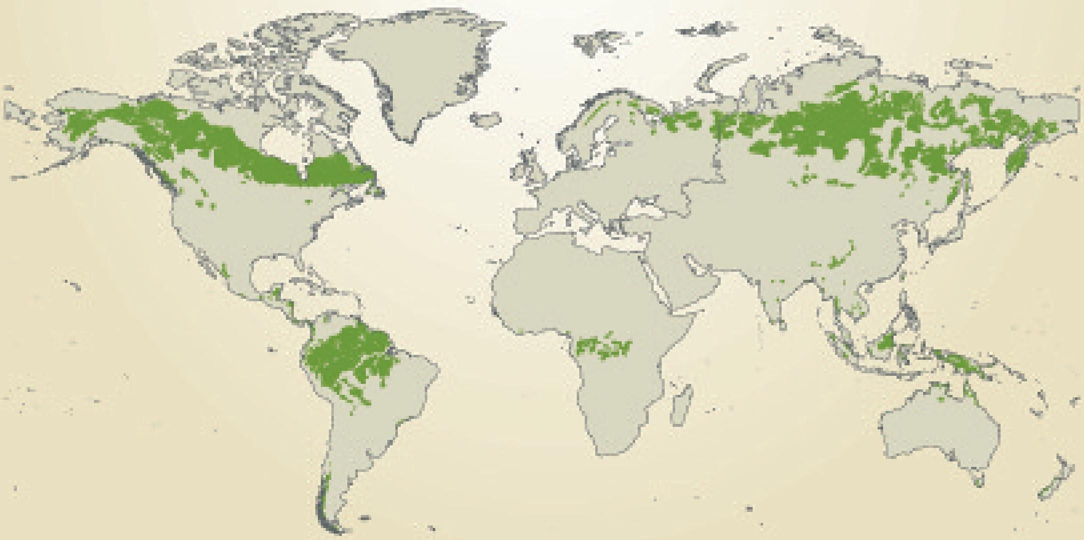

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