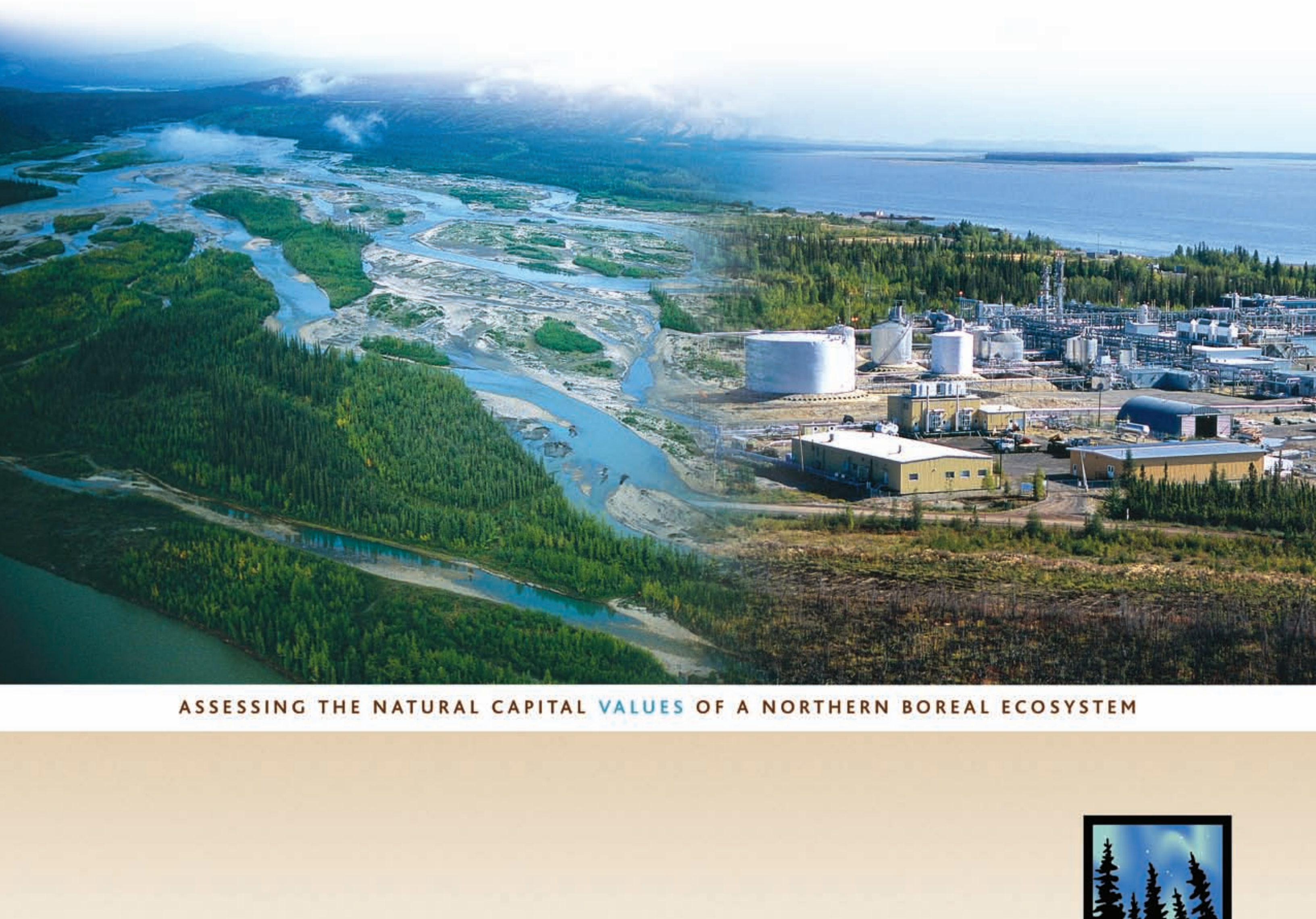
The Real Wealth of the Mackenzie Region



ASSESSING THE NATURAL CAPITAL VALUES OF A NORTHERN BOREAL ECOSYSTEM

CANADIAN BOREAL INITIATIVE

All cover photos: Garth Lenz

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 governments, First Nations, conservation groups, major retailers, financial institutions 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 system.

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Since 1999 Mark has been dedicated to developing alternative measures of economic progress, including the Genuine Progress Indicator (GPI) for the U.S. and Alberta, natural capital accounting, societal full cost accounting, Ecological Footprint Analysis, and quality-of-life measurement. His current focus and subject of his forthcoming book is *The Economics of Happiness: Building Genuine Wealth* (New Society Publishers, June 2007).

Mark is past-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 International Institute for Sustainable Development.

Mark has a master's degree in Forest Economics, and bachelor's degrees in Economics and in Forest Science, all from the University of Alberta. Mark lives in Edmonton with his wife, Jennifer, and their two young daughters.

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. Sara has also developed environmental policy alternatives, including initiatives that address climate change, pollution prevention, ecosystem conservation, and ecological fiscal reform.

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. She also authored *The State of Nova Scotia's Forests: Ecological, Social and Economic Values of Nova Scotia's Forests* and *The GPI Water Quality Accounts* as part of the GPI accounts for Nova Scotia.

Sara has training in environmental economics from the Smithsonian Institution in Washington, D.C., and a background in economic applications such as cost-benefit analysis and full cost accounting. She authored *The Costs and Benefits of Sewage Treatment and Source Control for the Halifax Harbour* 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 in International Development Studies and Environmental Geography. Sara currently lives in Gibsons, B.C., with her husband, Faisal, and their two children.

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Disclaimer

This study should be considered as a very preliminary and coarse-scale natural capital accounting of the Mackenzie watershed; the first step towards a more comprehensive accounting of natural capital assets in other watersheds and ecosystems across Canada. More Canadian research is needed into determining a full range of ecosystem service values relevant to Canadian ecozones and land-cover types. We encourage others to continue improving upon our work in the spirit of taking into fuller account the changes in ecological conditions and ecosystem service values of this vast natural capital treasure of the Mackenzie. These accounts are intended to stimulate a growing dialogue within Canada and abroad about natural capital measurement, stewardship, the real value of conservation, and how to take nature's wealth more fully into account in economic policy development and land-use planning decisions.

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 cannot guarantee that the information or valuation work 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. The material should thus be viewed as preliminary, and we welcome suggestions for improvements that can be incorporated into later editions of the study.

Carcajou Canyon, Mackenzie Valley, NWT, August 2005
Garth Lenz

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1. Executive Summary

This study is the first watershed-based natural capital review in Canada. Spanning 1.7 million square kilometres (or 170 million hectares), the Mackenzie watershed rivals the size and flow rates of the world's greatest river basins, including the Nile, Yangtse, and Amazon. The Mackenzie watershed is rich in other natural capital assets — intact forests, habitats for wildlife, rich sources of carbon, and vast deposits of oil, oil sands, natural gas and minerals. Yet, even given its significance, this great natural capital asset does not appear on Canada's national balance sheet nor do its ecological goods and services show up in the gross domestic product (GDP) — the traditional measure of economic progress.

It is both poor economics and poor accounting to not account for the total wealth of this region. Although Statistics Canada has begun to develop natural capital accounts for timber, oil, gas and agricultural soils, governments rarely use natural capital accounts in decision making. Effectively, we are operating blind to the total value of nature's wealth, which is critical to the well-being of northern and ecological communities, and to our country as a whole.

Natural capital accounting challenges us all to make decisions within a context of the full costs and benefits to drawing down that natural capital. For example, let's look at the value of carbon in today's economy. Over the past 100 years Alberta has expended over 30 percent of its net above-ground forest carbon capital — which in terms of the global social cost of carbon equates to an estimated **$9.6 billion loss.** Boreal ecosystems store more carbon in their peatlands, soils and trees than any other land-based ecosystem, including tropical rainforests. In a carbon-conscious world, our decisions for the future need to better reflect the broader natural capital values of the Boreal region.

The Canadian Boreal Initiative (CBI) has commissioned this study to help decision makers — federal, territorial, provincial and First Nations governments — make informed stewardship decisions that balance broader ecosystem and cultural values with sustainable economic growth. The study's primary goal was to construct a natural capital account for the Mackenzie watershed, including a total economic valuation of the market and non-market benefits of the watershed's natural capital.

The study's key findings:

- The market value of the Mackenzie watershed, assessed as the region's GDP, is estimated at $41.9 billion per year, an average of $245 per hectare.
- The non-market value of the watershed, assessed as the potential value of 17 ecosystem services produced by the region, is estimated at $448.3 billion per year, an average of $2,631 per hectare.
- The ecological goods and services provided by nature (e.g., carbon storage, water filtration, water supply) in the Mackenzie contribute over 10 times more societal economic value than the GDP generated by natural capital extraction industries. This evaluation is not intended to undervalue the resource potential, but rather to temper its value in a broader sustainability context.
- The industrial footprint in the region covers 25.6 million hectares and the estimated cost of natural capital degradation from development is likely to be in the billions of dollars. This does not suggest that natural capital extraction should cease, but rather that there be a more prudent approach to future natural capital stewardship, so that valuable ecosystem services can be maintained while meeting human needs and economic development objectives.
- The stored carbon and annual carbon absorbed by forests, peatlands, wetlands and tundra are valued at an estimated $252 billion in 2005, or 56 percent of the total estimated non-market value of ecosystem services.

This study builds on an earlier natural capital accounting study by the same authors completed in 2005, titled *Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems*, in which estimated ecosystem service values were contrasted with market (GDP) benefits of resource development. This study advances new valuation methodologies for ecological goods and services, building on the earlier Boreal wealth study, research by other ecological economists, and new carbon valuation methods, including the recent global carbon cost estimates by U.K. economist Sir Nicholas Stern.

The study shows the importance and real socio-cultural-economic value of conserving natural capital, and balancing sustainable development with protecting intact ecosystems for future regional and national benefits. The value of protecting the integrity of watersheds is exemplified by the safe and clean drinking water that over 9 million New Yorkers enjoy today as a result of a 1997 decision to invest in protecting their Catskill Mountain watershed. Also, the importance of conserving wetlands was poignantly demonstrated by the Hurricane Katrina disaster, which has resulted in repair costs of over US$80 billion to the State of Louisiana and New Orleans. These costs might have been avoided had the coastal bayou and natural wetlands been protected while advancing resource development.

The wisdom of respecting the inherent value of the land is well understood by Aboriginal peoples. For example, these values are expressed in the land and resource planning outcomes of the Dehcho Land Use Plan, NDÉH TS'EDÎÎCHÁ: Dehcho Ndéh T'áh Ats'et'î K'eh Eghálats'ênda, developed by the Dehcho Land Use Planning Committee for a 20 million hectare area of the Mackenzie watershed. The Plan recommends maintaining approximately 50 percent of the area in a natural state, and reflects, in the words of the committee,

"both the high value the Dehcho communities place on protecting the land and maintaining traditional land use and occupancy, and also their commitment to long-term stewardship."

The CBI and its collaborators believe in a balance between sustainable development and conservation. To advance this vision the CBI has formed long-term partnerships with Aboriginal communities, governments, industry, conservation groups, major retailers, financial institutions and others.

Figures 1 and 2 show the significant loss of frontier forest in North America over the past 100 or more years, with the majority of intact frontier forests now isolated in the northern regions of Canada's Boreal forest ecosystem, including the Mackenzie watershed. This underscores the importance of conserving natural capital in the Mackenzie watershed and the Boreal ecosystem.

Dehcho Ndéh T'áh Ats'et'î K'eh Eghálats'ênda – The Dehcho Land Use Plan

The Dehcho Land Use Plan is proposed for over 20 million hectares of the Mackenzie watershed. According to the final draft of the Dehcho Land Use Plan released in May 2006, Conservation zones (including permanent protected areas such as national parks and national wildlife areas) are proposed for approximately half of the planning area, while the remainder is open to well regulated development. In the general use and special management zones, land-use thresholds are established for mixed use areas in order to maintain wildlife habitat and other values, contributing to the preservation of natural capital. Thresholds are set for corridor/road density, habitat availability, minimum patch size and core areas, and stream crossing density. Overall, 64 percent of the oil and gas potential, 69 percent of the agriculture potential, and 88 percent of the forestry potential is available for development.

As the Dene note in their land use plan: "The level of conservation reflects both the high value the Dehcho communities place on protecting the land and maintaining traditional land use and occupancy, and also their commitment to long-term stewardship. It is consistent with the guiding principles of 'respect for the land as understood and explained by the Dehcho Elders, and sustainable development.'"

The Dehcho approach to natural capital stewardship may yield the highest potential in terms of both conventional economic benefits as well as ecological services contributing to genuine well-being over time.[1] Based on our analysis of ecological goods and services values by land cover type in their territory and assuming the full development of resources outside of the designated conservation zones, the potential ESP values could amount to $44.6 billion in 2005. By comparison, resource development activities would return an estimated GDP of $9.2 billion as per the Dehcho land use plan, compared to $13.3 billion under the full development scenario over 20 years.

Figure 1: Original frontier forests in North America. Mackenzie watershed is identified by a red boundary line.

Source: World Resource Institute

Figure 2: Remaining frontier forests in North America and in the Mackenzie watershed.

Source: World Resource Institute

2. Introduction

In 2005 the Canadian Boreal Initiative (CBI), in partnership with the Pembina Institute, released a study by ecological economists Mark Anielski and Sara Wilson to develop the first natural capital account of Canada's vast Boreal ecosystem, which covers 58 percent of Canada's land mass. The Boreal natural capital study demonstrated the importance of accounting for both the market and non-market values of Canada's natural capital assets, and in particular the value of ecological goods and services that currently are unaccounted for in Canada's national and provincial income accounts and in the gross domestic product (GDP), the key measure of economic prosperity. The Boreal study showed that the non-market ecosystem services could be worth about 2.5 times more than the GDP generated by harvesting timber, extracting oil, gas and minerals, and generating hydroelectricity. The study also found that the Boreal's unaccounted ecosystem services had an annual value equivalent to 9 percent of Canada's GDP, an amount comparable to Canada's health and social services, plus half the entire public service sector. The study, which garnered international recognition, confirmed the global importance of the vast storehouse of carbon contained in the Boreal's wetlands, peatlands and forests.

The primary goals of the present study are to:

1) Compile a natural capital balance sheet of the existing state of Canada's Mackenzie watershed Boreal region;
2) Provide economic estimates of the value of the Mackenzie watershed's market-based and non-market ecosystem services;
3) Highlight the merits of taking a balanced approach to conservation, development and community health in the broader Mackenzie watershed; and
4) Appropriately reflect Aboriginal perspectives and community values.

Our intention is to inform decision makers about how the ecosystem services of the Mackenzie watershed contribute to societal well-being.

Natural capital, which includes both renewable and non-renewable natural resources, and ecosystem goods and services, is critical to the economic and social well-being of Canadians. But natural capital, Canada's most important asset, goes unmeasured and its real value is not expressed in monetary terms.

Several critical questions follow from this: How can these natural capital assets be accounted for in a new and expanded balance sheet for the nation and provinces? How should the importance of ecosystem services from natural systems be measured in economic, ecological and social terms? How important is the natural capital of the Mackenzie to the communities in the watershed, to the rest of Canada, and to the world? How can the real value of these assets be measured, and how should we value them in both monetary and quality-of-life terms?

This study is the first natural capital account of a watershed in Canada that establishes a preliminary account of the spatial distribution of natural resources, land covers and ecozones, and their respective economic, societal and ecological values at the scale of the Mackenzie watershed. These natural capital accounts were developed in accordance with the United Nations[2] natural capital accounting guidelines, and the results of the economic values were developed in the Boreal Ecosystem Wealth Accounting System (BEWAS) in the Boreal study. This study advances new spatial satellite imagery for assessing natural capital inventories, and adopts new ecological valuation methods that we hope will help decision makers balance the goals of economic development with sustained ecological goods and services through wise stewardship and conservation. The ultimate goals are to recognize the real wealth of the Mackenzie and to promote policies to preserve natural capital as a vital aspect of the well-being of Canadians, now and for the future.

This report represents a first step. Further work could be undertaken to assess the cumulative ecological impact of industrial development and associated losses in "Ecosystem Services Product" (ESP) compared to GDP per unit of natural capital consumption. This would enable decision makers to better understand the trade-offs involved in land use decisions.

3. Background on the Mackenzie Watershed

The Mackenzie watershed (Figure 3) covers over 170 million hectares, an area 2.6 times the size of the province of Alberta. It incorporates 61 percent of Alberta's land base, 59 percent of the Northwest Territories, 28 percent of British Columbia, 26 percent of Yukon, 17 percent of Saskatchewan and 0.1 percent of Nunavut.

The watershed includes the Mackenzie River, Canada's longest river at 4,241 kilometres, which carries one fifth of the country's freshwater and nutrients to the Arctic Ocean. The Mackenzie rivals the world's great rivers — the Nile, Congo, Yangtse, Lena, Indus, Rhine and Amazon — in size and flow rates, but is unique in that it remains in a mostly natural state. Other major rivers in the watershed include the Peace River (1,923 kilometres), the Athabasca River (1,231 kilometres) and the Liard River (1,115 kilometres). The Mackenzie River's massive streamflow of 507 square kilometres is about 15.2 percent of Canada's total streamflow of 3,315 square kilometres. Only a small fraction (0.4 percent, or 12.2 million cubic metres) of the Mackenzie River's total streamflow discharge of 305,899 million cubic metres is currently being used by municipal, industrial and agricultural users.

The Mackenzie watershed has sustained Aboriginal peoples for millennia, and also supports a large city, Edmonton (pop. 900,000), and many smaller communities, including Ft. McMurray, Alberta (pop. 78,792),[3] Grande Prairie, Alberta (41,125),[4] Yellowknife (16,541),[5] and Fort St. John, B.C. (16,034).[6] Figure 4 shows the human settlements in the watershed.

The Mackenzie watershed is 28 percent of the land area of Canada's massive Boreal ecosystem, and is one of its largest, most natural, and most intact portions. An estimated 6.3 percent of the watershed is protected from industrial development through designations as national parks, provincial parks, and recreation areas. It provides habitat to hundreds of species of birds, some of the world's largest herds of barren-ground and woodland caribou, and a rich diversity of other wildlife.[7] It is also a region of intact, unfragmented forest (an estimated 66 percent of the total, or 112 million hectares) and other ecosystems.

The watershed also contains vast deposits of oil, natural gas, and minerals, which have the potential to generate many billions of dollars in investment and GDP for the economies of western

Ts'ude niline Tu'eyeta community workshop, April 2004
PACTeam Canada

Canada. Within the watershed are vast oil sands deposits — which occur as a mixture of crude bitumen (a semi-solid form of crude oil), silica sand, clay minerals, and water — covering over 14.1 million hectares in northeastern Alberta and northwestern Saskatchewan. The oil sands, which lie beneath Boreal forest and muskeg (peat bogs), contain an estimated reserve of 174 billion economically recoverable barrels of bitumen oil.[8] This vast oil reserve is the world's second largest after Saudi Arabia's estimated 240 billion barrels.

In addition, the Mackenzie Delta–Beaufort Sea natural gas fields contain natural gas reserves that are critical to the long-term economic viability of the oil sands development. The proposed Mackenzie gas pipeline, now undergoing regulatory and environmental review, could become the most costly development project ever attempted in the Arctic, with an estimated price tag of between $7 billion and $10 billion. According to Sproule Associates Ltd., the Mackenzie Delta–Beaufort Sea Basin is estimated to contain 10.9 trillion cubic feet of discovered and 45.8 trillion cubic feet of undiscovered marketable natural gas[9] worth roughly $115 billion (valued in 2005 dollars, and based on the average Canadian producer sales price of natural gas in 2005 of $10.57 per thousand cubic feet).[10] Marketable gas reserves are roughly 26 percent of Alberta's current 41.7 trillion cubic feet[11] of remaining natural gas reserves. As the commercial and economic benefits of these reserves are advanced, decisions should reflect and be balanced with the need to also protect ecosystem and community values.

Figure 3: Mackenzie watershed relative to Canada's Boreal forest ecosystem.
Source: geogratis.cgdi.gc.ca

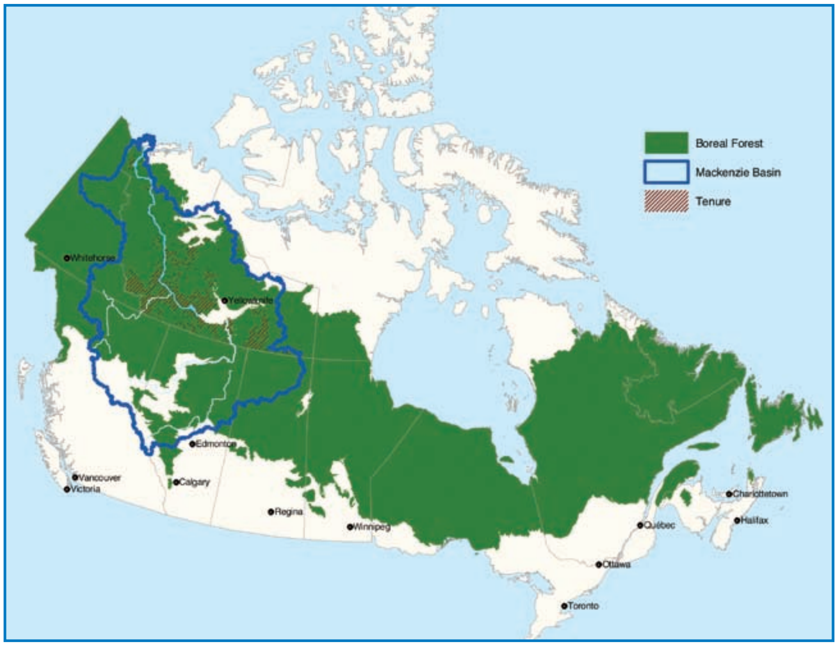
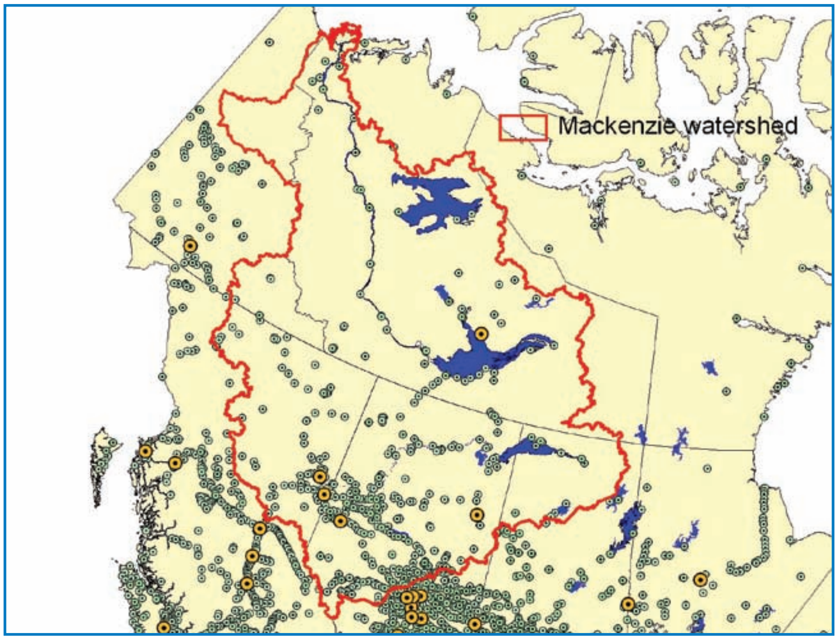


Figure 4: Human settlements in the Mackenzie watershed. Yellow circles represent larger settlements.
Source: Global Forest Watch Canada



4. Why Account for Natural Capital?

The GDP is the key indicator of economic performance but it measures only the market value of economic activity, including that of converting (harvesting) natural capital assets such as timber, oil, gas, minerals and agricultural soils into monetary income. GDP is not, however, a measure of welfare or well-being since it does not account for unsustainable levels of natural resource extraction, natural capital depreciation, the full costs of pollution, subsidies to resource industries, or most important, the non-marketed services of nature in providing clean air, water and other ecological goods and services.

The Mackenzie watershed's rich ecological assets include Boreal forests, wetlands, peatlands, fens and bogs, and tundra, which together provide ecological goods and services: water filtration, carbon storage, pest control by birds, climate regulation, cultural benefits to Aboriginal communities, recreational benefits and opportunities for a wide range of land users.

Natural capital accounting helps to bring ecosystem values more fully into decisions relating to development, and onto national and provincial balance sheets. Operating without natural capital accounts is akin to a major energy company operating without an account of its oil and gas reserves.

In conventional economics a natural asset such as a wetland is often considered valuable only until it becomes scarce or its ecological services are so degraded that human infrastructure is required to replace the original services provided free by nature. For example, often we must build water treatment facilities to clean our water—a service that was once provided free of charge by wetlands.

Yet because the ecological services provided by ecosystems go unaccounted for in national and regional economic balance sheets and in the GDP, they literally count for nothing. Since the 1990s Statistics Canada has been a leader in developing natural capital accounts for timber, oil, gas and agricultural soils, but governments rarely factor these accounts in policy decision making, and are thus effectively operating blind to the real value of nature's wealth.

The loss of the ecosystem service value of assets like wetlands and peatlands sometimes has regrettable outcomes. For example, the devastation caused by Hurricane Katrina, which has resulted in repair costs of over US$80 billion to the State of Louisiana and New Orleans, is a poignant example of the real value of preserving natural assets such as New Orleans' destroyed bayou and natural wetlands — assets that served as a natural protective barrier against hurricane surge waves. Allowing the destruction of these ecological assets is simply bad economics and poor asset management — if the goal of society is to achieve genuine well-being and optimum value from all ecological wealth.

Accounting for the value of natural capital — in physical, quality and economic terms — would help to reveal their present condition and importance to our economic well-being now, and more important, in the future, as natural landscapes untouched by human development become scarce.

The Real Value of New York's Watershed[12]

The Catskill watershed covers roughly 80,000 acres (32,389 hectares) in the Catskill Mountains located northwest of New York City. The forested watershed is a natural filtration system that provides over 9 million New York City residents with 1.1 billion gallons of clean drinking water every day. The U.S. Environmental Protection Agency estimates that throughout the U.S., over 3,400 public water systems serving 60 million people obtain their water from forested watersheds, which must be in relatively integral condition to provide sustained services of potable water.

The value of protecting and conserving forested watersheds came to the forefront in 1997 with New York City's progressive decision to invest US$1.5 billion to protect the Catskill watershed instead of building yet another water filtration plant. The plant would have cost $6–8 billion to build, plus $300–500 million to maintain.

While it's difficult to draw a direct parallel between New York and the Mackenzie watershed, it is interesting to compare water values. If we adjust New York watershed values from 1997 to 2006 values, and apply them to the Mackenzie watershed (170 million hectares), the fresh water from the Mackenzie watershed would be worth over $1 trillion a year!

5. Canada's Natural Capital Advantage

According to total wealth accounts developed by the World Bank — based on natural, human, social and built capital — Canada is one of the richest nations on Earth when it comes to natural capital. In 2000 Canada ranked third in per capita natural capital asset values (timber, oil, gas, coal, cropland, pasture land, non-timber forest resources, protected areas) with a value of US$34,771 per capita. Only Norway (US$54,828 per capita) and New Zealand (US$43,226) ranked higher. By comparison, the U.S.'s natural capital assets are worth only $US14,752 per capita.

According to these World Bank estimates, Canada's natural capital was valued at US$1,070 billion in 2000, or 10.7 percent of Canada's total wealth, valued at US$10 trillion (US$324,978 per capita). Canada's total wealth includes produced capital and urban land (US$1,668 billion; 16.7 percent of total wealth) and human, social and institutional capital (US$7,261 billion; 72.6 percent of total wealth).[13]

What the World Bank's estimates ignore, however, is the non-market value of ecosystem services from nature. In a global study of the value of ecological services from natural ecosystems, ecological economist Robert Costanza and geographer Paul Sutton estimate that Canada is second only to Russia in what they call Ecosystem Services Product (ESP), the equivalent of GDP for non-market ecological goods and services provided by nature.[14] Canada's ESP value for both land and marine ecosystems is estimated at US$5,611 billion (US$182,353 per capita) in 1995 compared to a GDP of $694 billion (Purchasing Power Parity). The nation's ESP values are therefore more than 8 times greater than its GDP. If ESP and GDP are added together then a subtotal economic-ecological product (SEP) could be derived at US$6,306 billion.

Rouge Mountains, Mackenzie Valley, NWT, August 2005
Garth Lenz

6. Methodological Approach

The study's primary goal was to construct a natural capital account for the Mackenzie watershed, including the land area and natural capital assets (e.g., timber, oil, gas) by land-cover type, and a total economic valuation of the market (GDP from commercial use of natural capital) and non-market (ecological goods and services) values of the watershed's natural capital.

6.1 Physical Natural Capital Inventory

The physical accounting of natural capital in the Mackenzie was conducted using spatial satellite imagery of land cover to estimate the area of each land-cover type and anthropogenic disturbance (linear disturbance by oil, gas, mining, and forestry developments).

6.2 Market Value of Natural Capital

The market value of natural capital consumed for commercial and private benefit is based on GDP estimates. There are currently no data on GDP or economic activity by industrial activity (forestry, oil, gas, mining, agriculture) at the spatial scale of the Mackenzie. Generally, GDP statistics are not available for areas smaller than large municipalities like Edmonton or Calgary, and must therefore be estimated with other proxies.

For this study we used two approaches to estimate the GDP of the Mackenzie. First, we estimated the GDP per hectare of land currently allocated to the forestry, oil, gas and mining, and agricultural sectors by mapping the spatial area (i.e., industrial footprint) currently being used for those sectors' various commercial uses. For forestry activity, we considered the productive forest land area and estimates of the area of timber harvested in 2005, upon which forestry GDP values are derived. For oil, gas and minerals, the industrial footprint was based on the spatial industrial footprint from well sites, pipelines, seismic lines and other linear disturbances related to this sector. Agriculture's footprint was based on estimates of cropland from the land-cover mapping. Estimates of GDP per hectare of industrial land use were taken from the Boreal wealth accounts, which were derived from national GDP figures for each sector: (primary and manufacturing industries included), forestry, mining (oil and gas, included) and agriculture. This yielded estimates of GDP value per hectare of land under various commercial natural capital uses.

In the second, more innovative approach, we estimated the GDP for the entire Mackenzie watershed using night-time satellite images of light emissions for Canada and specifically for the Mackenzie region. Our research methods were similar to those used by Doll et al. (2005), Sutton (2003) and Sutton and Costanza (2002).[15] We used recent global night-time light satellite imagery for Canada and the Mackenzie (see Figure 6) to derive light emission intensity spatial hectares (58,160 hectares of LE)[16] and correlated light emission (LE) data with the distribution of GDP across all provinces. The result is a relatively good statistical relationship (R square = 0.80) of provincial GDP intensity and light emission intensity. For example, it was estimated that the areas with the highest light emission generate $720,004 of GDP per hectare of LE. We believe these estimates are reasonable given that Calgary's estimated GDP per hectare of municipal land area for 2004 is $774,194 (Anielski Management Inc., 2006).[17] Of course, the highest GDP intensity is in municipalities where economic activity is most concentrated. Since light emissions are more diffuse in less populated and remote areas like the Mackenzie, we would expect much lower GDP per hectare of LE.

6.3 Non-Market Value of Ecosystem Services

In addition to estimating the GDP or market value of natural capital assets in the Mackenzie watershed, we estimated the ESP of ecological goods and services for each land-cover type. The approach to ESP valuation is based on Sutton and Costanza (2002)[18] in which 17 possible ecosystem functions (see Table 1) are evaluated in terms of potential non-market benefits. In some cases, functions are 'quasi-market' in nature, that is, market-related services like food production, recreation, culture, raw materials and genetic resources. However, for purposes of this study we did not isolate these quasi-market values from other ecosystem service functions, including special analysis for the value of peatlands. Because there is insufficient room in this report to provide methodological details on how each ESP value was determined for each of the 11 land covers, interested readers should contact the principal researchers of this report.

Drawing from background research conducted for the two-year Boreal wealth study, we updated several ecosystem service value estimates. Each of the 17 possible ecosystem service values (many of these values are not available) were closely scrutinized as to whether we felt they would yield a fair non-market estimate of the various land-cover types in the Mackenzie. For several assets, including carbon and water values, we considered them to be of global strategic importance and felt they warranted values that reflected their global significance. In some cases, such as recreation values, we used our own Canadian value estimates based on previous research into the value of nature to Canadians (see *Counting Canada's Natural Capital* report). If we could not find a suitable Canadian value for an ecosystem service function we deferred to estimates made by Costanza et al. (1997). With a value per hectare land-cover approach, our analysis was much simpler since we could map land cover by type across the watershed. This approach made it ideal to estimating ecosystem service values for each land-cover type.

As previously noted, the most significant departures from the Boreal wealth accounts from 2005 include:

- Ecosystem service values are estimated according to land-cover type using 17 possible ecosystem goods and services (see Table 1).
- Estimates of the annual flow of service values from the stock of stored carbon[19] in peatlands, forests, and tundra, as well as the annual value of net sequestration of carbon, are included. The annual value of carbon stored by ecosystems is converted to an annuity to yield an annual value stream of global benefits of the carbon stored in the Mackenzie watershed.
- Carbon value is based on the social cost of carbon from Britain's *Stern Review on the Economics of Climate Change*. The review calculates the economic impacts of climate change over time, if the world continues on a business-as-usual (BAU) scenario. The social cost of carbon under a BAU scenario is estimated at US$85 per tonne of CO2 (US$23.16 per tonne of carbon; 2000$) now, and rising over time. We converted the current value as C$38.60 per tonne of carbon (2005$). It is important to note that the Stern Review is based on the latest science, which predicts greater increases in global average temperature (up to 5 degrees Celsius, compared with previous estimates of 2 to 3 degrees C).
- Water bodies ecosystem services, including water regulation and water supply, were valued using the previous estimates by Costanza et al. (1997) given the global significance of the Mackenzie River and watershed. Water was not evaluated in the Boreal wealth study.

Norman Wells, Mackenzie Valley, NWT, August 2005
Garth Lenz

Table 1: Ecosystem services, their functions and valuation methods[20]

Ecosystem Service	Ecosystem Function	Valuation Methods Used in Mackenzie Wealth Accounts[21]
Atmospheric stabilization	Stabilization of atmospheric chemicals	Grassland and mosaic values estimated based on Costanza et al (1997).
Climate stabilization	Regulation of global temperature, precipitation, and other climate processes	Forests, peatlands and tundra permafrost values; new carbon value estimates for both stocks and annual sequestration values.
Disturbance avoidance	Integrity of ecosystem responses to environmental fluctuations	No ecological values available.
Water stabilization	Stabilization of hydrological flows	Costanza et al. (1997), based on global average water stabilization value estimates for grass/rangelands and water bodies land cover only.
Water supply	Storage and retention of water by watersheds	Anielski and Wilson (2005), using average Alberta municipal water pricing applied to forest cover; global average value for wetlands from Anielski and Wilson (2005); Costanza et al. (1997) value used for lakes and rivers.
Erosion control and sediment retention	Retention of soil within an ecosystem	Costanza et al. (1997), grass/rangelands and mosaic land cover.
Soil formation	Soil formation process	Costanza et al. (1997) only for grass/rangeland and mosaic land cover.
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	No ecological value estimates available.
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	Costanza et al. (1997) for grass/rangelands, mosaic land cover, and water bodies.
Pollination	Movement of floral pollinators	Costanza et al. (1997) for grass/rangelands, mosaic land cover, and cropland.
Biological control	Regulation of pest populations	Anielski and Wilson (2005) for each land cover except barren/tundra/permafrost, snow/ice, wetlands, and water bodies.
Habitat/Refugia	Habitat for resident and transient populations	Anielski and Wilson (2005) for all land cover except cropland, grass/rangeland, snow/ice and water bodies.
Food production	That portion of gross primary production extractable as food (subsistence farming, fishing and hunting).	Anielski and Wilson (2005) for all land cover except cropland and snow and ice. Water bodies value is from Costanza et al. (1997); updated Non-Timber Forest Products values based on 2005 national estimates from Canadian Forest Service.
Raw materials	Natural resource primary production (lumber, fuels, fodder, fisheries, crops)	Global average value for wetlands from Anielski and Wilson (2005), wetlands and peatlands only.
Genetic resources	Sources of unique biological materials and products	Global average value for wetlands from Anielski and Wilson (2005), wetlands and peatlands only.
Recreation	Opportunities for recreation	Anielski and Wilson (2005) for all land cover types except cropland, snow and ice, and barren/tundra/permafrost; significantly lower than Costanza et al. (1997)
Cultural	Opportunities for non-commercial uses: aesthetic, artistic, educational, spiritual, scientific, Aboriginal sites	Anielski and Wilson (2005), for only forested land cover types.

Key Findings

- The market-based GDP generated within the Mackenzie watershed in 2005 was estimated at $41.9 billion, or an average $245 per hectare of the total watershed. GDP for the region was estimated using light energy (LE) data from night-time satellite imagery, which was found to be statistically correlated with GDP intensity in the western provinces. In addition, GDP estimates for agriculture ($878 million), forestry ($2.74 billion), and oil, gas and mining ($21.98 billion) for 2005 were estimated based on previous GDP per hectare estimates in the Boreal wealth study, but used 2005 sector GDP data from Statistics Canada. The GDP of these three major sectors totals $25.6 billion or 61 percent of the GDP for the total watershed. However, this figure does not account for the costs of industry subsidies and pollution, which were estimated in the Boreal wealth study.

- The potential Ecosystem Services Product (ESP) value — an equivalent measure to GDP for market-based natural capital development — for the entire Mackenzie watershed is estimated at $448.3 billion per year or $2,631 per hectare per year as of 2005. By potential we mean what each land cover and ecozone is capable of producing in ecosystem services in a natural, flourishing or integral condition, with a full range of functionality of some of the 17 ecosystem services. These potential ESP values do not appear in either Canada's national balance sheet or current GDP figures. Our ESP values calculated for the Mackenzie are considerably higher because we have considered a broader suite of ecosystem service values and have used more sophisticated carbon accounting and valuation methods.

- The ecological cost of progressive natural resource development is a significant and growing industrial footprint, which satellite imagery analysis estimates at 25.6 million hectares, largely due to linear disturbance from oil, gas and mining activity. In addition, 2.0 million hectares of forest land have been harvested since 1950, and 3.4 million hectares of once-frontier forest are under crop and other agricultural production. Without solid research we do not know the relationship between the industrial footprint and anthropogenic disturbance of these ecosystems and their relative loss in ESP values. However, we can safely assume that losses in ESP value or ecological depreciation costs could range from 0 to 100 percent, depending on the significance of the impact and which ecosystem functions are affected. For example, if we assumed a 50 percent loss in ESP values from the cumulative industrial footprint we measured, this would equate to a net loss in ESP values of $67.3 billion in 2005 or a 15 percent loss in potential ESP value. This figure would be deducted from the potential ESP values to derive an adjusted ESP for ecological degradation, which would then be compared with GDP values.

- If we were to combine GDP and an ESP (adjusted for ecological depreciation using our 50 percent loss example) this would yield a subtotal ecological-economic product (SEP) estimate of $381.0 billion. By this example we could conclude that in 2005 the benefits of $41.9 billion in GDP from natural capital commercialization have come at an ecological depreciation cost of $67.3 billion.

- Even if these sustained losses in ESP values were manifest, the ecological goods and services provided by nature in the Mackenzie still contribute over 10 times more economic value than the GDP generated by natural capital extraction industries. This does not suggest that natural capital extraction and commercialization should cease, but rather that there be a more prudent approach to future natural capital stewardship that would attempt to realize the highest possible benefits from the ecosystem services while consuming natural capital to meet human needs and economic development objectives.

7. Study Results

7.1 Land Cover

The three largest land covers in this 170 million hectare watershed, in order of size, are Boreal evergreen needleleaf, mixedwood and barren land (including tundra). Table 2 shows the area of each land cover, and the area of each ecozone.

7.2 Market GDP Values from Natural Capital Development

Table 3 shows the estimated GDP generated by each sector in 2005. The GDP for forestry was $2,744 million ($200 per hectare of productive forest land). Mining, oil and gas generated an estimated GDP of $21,983 million ($821 per hectare of land used for mining, oil and gas development), and the GDP for agriculture (crops and animal production) was estimated at $878 million ($255 per hectare of cropland area). These numbers are course-scale estimates.

Figure 5: Mackenzie watershed land cover map

Source: Global Forest Watch Canada

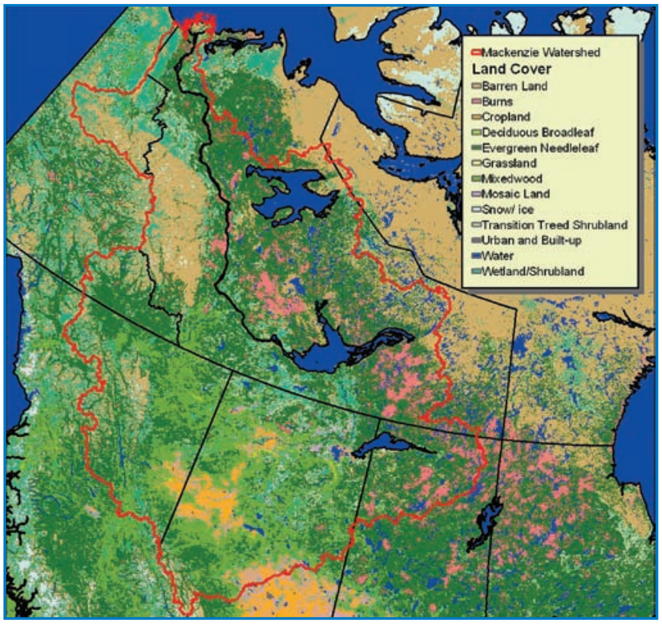


Table 2: Mackenzie watershed area by land-cover type and by ecozone type (hectares)

Source: Global Forest Watch, 2007

Land cover by type	Area of land cover (hectares)
Barren Land	25,031,600
Burns	8,719,600
Cropland	3,437,200
Deciduous Broadleaf	420,700
Evergreen Needleleaf	62,926,800
Grassland	33,200
Mixedwood	23,818,600
Mosaic Land	2,660,600
Snow/ice	720,400[22]
Transition Treed Shrubland	15,226,800
Urban and Built-up	5,700
Water	12,275,500
Wetland/Shrubland	15,113,100
Mackenzie watershed (total)	170,389,800

Ecozones by type	Area of ecozones (hectares)
Boreal Cordillera	15,433,100
Boreal Plains	36,999,400
Boreal Shield	8,146,500
Montane Cordillera	8,238,100
Prairies	3,400
Southern Arctic	3,161,100
Taiga Cordillera	13,921,700
Taiga Plains	58,188,800
Taiga Shield	26,297,000
Mackenzie watershed (total)	170,389,800

Table 3: GDP values for various sectors in the Mackenzie watershed

	GDP market value, $ millions, 2005	GDP market value, $/ha, 2005
Forestry	2,744	200
Mining, Oil and Gas	21,983	821
Agriculture (crops and animal production)	878	255
Other non-resource sectors (measured as a residual)	16,270	n/a
Total GDP of Mackenzie region	**41,875**[23]	**246 (avg.)**

Unlike the Boreal wealth accounts, this study did not estimate the government subsidies to various industries, pollution costs or other externalities such as the cost of carbon emissions from industrial activity. As the Boreal wealth accounts showed, these costs can be significant — roughly 23 percent of the value of market GDP generated by the sector — which should be deducted from GDP as a depreciation cost of other natural, human and social capital.

Based on the light emission analysis we totalled GDP in the Mackenzie watershed at $41,875 million or $245.75 per hectare. Using this figure and netting out the forestry, mining and agricultural GDP estimates (52 percent of the region's GDP) we derived a residual GDP for all other sectors of $16.27 billion. We also estimated that 39 percent of Canada's total GDP from oil, gas, mining extraction and product manufacturing comes from the Mackenzie watershed. In addition, the $41.9 billion GDP estimate for the Mackenzie watershed represents roughly 9.6 percent of the GDP of the provinces and territories that make up the Mackenzie (Alberta, B.C., Saskatchewan, Northwest Territories and Yukon), even though by area the Mackenzie watershed represents 27.6 percent of the combined land mass of these provinces and territories.

Figure 6: Light emission map of Mackenzie watershed showing major cities and towns.

Source: Global Forest Watch Canada

7.3 Ecosystem Services Product (ESP) Values: Measures of the Socio-economic Value of Ecosystem Functions, Goods and Services

The results of our analysis are summarized in Table 4. The greatest ESP values are estimated for water bodies ($153.2 billion), wetlands and peatlands ($144.4 billion) and barren lands (tundra/permafrost) ($83.8 billion). The key contributors to ESP values for these land-cover types include the important value of climate regulation, namely carbon storage and annual carbon sequestration services, and water stabilization, regulation and supply.

A more detailed breakdown of ESP values by land cover is shown in the Appendix.

7.4 Estimating the Loss of Ecological Goods and Services from Development

To account for the impact of oil, gas, forestry and agricultural development we used satellite imagery to map the extent of linear disturbance associated with these activities and then overlaid these on the land-cover map to estimate how much land cover has been impacted by industrial and other human development. The Boreal wealth report released in 2005 showed a massive and growing industrial footprint from oil, gas, mining and forestry development across the Boreal forest, with the greatest linear disturbance and loss of ecosystem integrity in Alberta.

A similar analysis was conducted for the Mackenzie, mapping the linear disturbance impacts for seismic lines, pipelines, well sites, roads and other oil, gas, forestry and agricultural development (see Figure 7).[26] All anthropogenic disturbances were mapped and

Table 4: Ecosystem Services Product (ESP) value estimates for ecosystem functions

Land cover by type	Area of land cover (hectares)	Estimated ESP per hectare (C$/ha, 2005)	Total ESP ($ millions, 2005)
Barren Land (Tundra/permafrost)	25,031,600	$3,946[24]	$83,765
Burns	8,719,600	332	2,901
Cropland	3,437,200	86	297
Deciduous Broadleaf	420,700	665	280
Evergreen Needleleaf	62,926,800	665	41,878
Grassland	33,200	368	12
Mixedwood	23,818,600	665	15,851
Mosaic Land (cropland and native vegetation)	2,660,600	227	604
Snow/ice	720,400[25]	N/A	N/A
Transition Treed Shrubland	15,226,800	333	5,067
Urban and Built-up	5,700	1,454	8
Water Bodies (rivers, lakes)	12,275,000	12,844	153,250
Wetland/Shrubland	15,113,100	5,310	144,423
Mackenzie watershed (total)	**170,389,800**	**$2,631**	**$448,336**

Note: Wetland/shrubland land cover refers to exposed wetlands. However, the estimated ESP value ($144,423 million) is calculated for exposed wetlands and 14.925 million hectares of peatland that lies underneath the forest cover. Peatlands are a type of wetland which contain more than 40 cm of peat (organic material). Most wetlands in Canada are peatlands (>90%) and virtually all wetlands in the Mackenzie watershed are peatlands.

buffered by 500 metres on each side. This buffering was made to accommodate an ecological footprint and to accommodate some orthorectification challenges. Figure 7 shows how large the industrial footprint has already grown, with dramatic progression north of Alberta's rich oil and gas fields, along the Mackenzie River, and towards the Mackenzie Delta. The industrial footprint of oil, gas, and mining activity in the Mackenzie watershed alone is now 26,768,800 hectares, or 15.7 percent of the entire watershed area. The cumulative impact of forest harvesting (1950–2004) is estimated at 2.1 million hectares on a potential productive forest land base of 24.9 million hectares; thus 8.3 percent of the productive forest land base has been harvested over the past 50 years. The area of forest harvested annually varies but is estimated to be rather stable, around 80,000 hectares per year.

Table 5 provides analytical results of how much area within each of the 11 land-cover types has been impacted by linear disturbance, and, we believe, is thus experiencing potential stresses or losses in several ecosystem functions.

Figure 7: Anthropogenic disturbances and industrial footprint (oil, gas, minerals, agriculture, forestry development) in the Mackenzie watershed.
Source: Global Forest Watch Canada

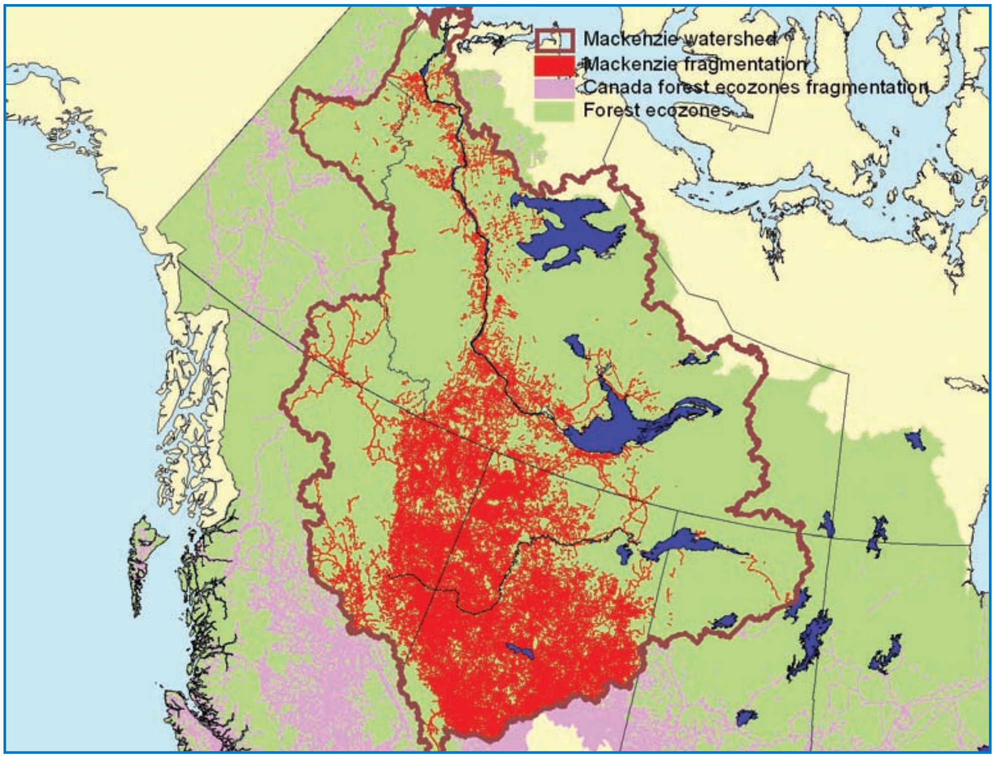


Table 5: Mackenzie watershed land-cover types impacted by linear disturbance from industrial development, 2005

Land cover by type	Current land area (ha)	Land area disturbed by industrial development	% of watershed land-cover types affected by industrial development (proxy for loss of ecosystem functions)
Barren Land	25,031,600	230,332	0.9%
Burns	8,719,600	571,217	6.6%
Cropland	3,437,200	2,143,644	62.4%
Deciduous Broadleaf	420,700	123,375	29.3%
Evergreen Needleleaf	62,926,800	8,639,958	13.7%
Grassland	33,200	2,393	7.2%
Mixedwood	23,818,600	8,990,809	37.8%
Mosaic Land	2,660,600	1,182,487	44.4%
Snow/ice	720,400	612	0.1%
Transition Treed Shrubland	15,226,800	1,946,108	12.8%
Urban and Built-up	5,700	5,288	92.8%
Water	12,275,500	347,710	2.3%
Wetland/Shrubland	15,113,100	1,401,686	11.4%
Total Mackenzie watershed	**170,389,800**	**25,585,619**	**15.0%**

While the loss of integrity of Boreal ecosystems can be seen from space by satellite, and the spatial ecological footprint can be measured, it is difficult to translate this fragmentation and loss of ecological integrity into losses in the value of ecological goods and services. For the most part, we simply do not know how reaping the economic benefits of oil and gas development today will affect our future economic and ecological well-being. These ecological impacts constitute unfunded ecological liabilities, which future generations may have to pay for through environmental cleanup costs, or through the costs of building water treatment facilities to replace the services of destroyed wetlands. Not accounting for these ecological benefits and the accompanying ecological, social and economic costs is akin to ignoring the value of the health, social services and the public service sectors in our national income accounts. In the absence of perfect knowledge, we should at the very least adopt a conservative account of the change in the integrity of these important ecosystems.

The relationship between anthropogenic disturbance in once-intact ecosystems and the loss of ecosystem services and their economic value is poorly understood. We do know from experience that when human pressures reach a certain threshold, ecosystems can experience dramatic tipping points or collapse. Determining where or when these ecological tipping points might occur is impossible.

How then should we estimate the value of the potential liability to ecosystem services from ongoing industrial development? We suggest that a range of potential ESP value losses or ecological depreciation costs could be used, from 0 to 100 percent of potential ESP values depending on the land cover or ecozone type, and in relationship to the degree of anthropogenic disturbance. If, for example, we determined a 50 percent loss in ecosystem service functions and their value due to the current cumulative industrial footprint, we would estimate the net loss of ESP values of $67.3 billion. In financial accounting terms this would be equivalent to measuring the depreciation costs of built capital or infrastructure from the erosion of their utility or services. We would then deduct the $67.3 billion from the estimated $448.3 billion potential ESP values to derive an adjusted ESP value that reflects the loss of ecosystem integrity or depreciation. The 50 percent loss estimate is, of course, simply an illustration of how ecosystem depreciation costs might be factored into natural capital accounting. More research is needed into how industrial and human development actually impacts the various ecosystem functions by land-cover type. We welcome debate supported by more empirical analysis and primary research.

7.5 Changes to Alberta's Ecological Capital

According to a cumulative impact analysis carried out by biologist Brad Stelfox on the industrial and agricultural development in Alberta over the last 100 years, the texture and composition of Alberta's landscape has profoundly changed. The land uses that have shaped the province — trapping, agriculture, forestry, energy, transportation, residential development, and tourism — have each provided significant socio-economic benefits. These benefits, however, have accrued through significant draw-downs on Alberta's ecological capital, and in the social and economic services that natural capital provides.

Looking at Alberta's forest ecosystems, they have sustained tremendous industrial development pressures in two key ways. First, several million hectares of forest have been lost due to crop cultivation, urban and community expansion, transportation, and the energy sector. Second, the forest age structure has progressively changed toward younger forests. This transformation in age structure has been caused by the additive disturbance rates caused by logging, fire, and insect outbreaks.

Stelfox estimates that approximately 250 million tonnes of forest biotic carbon have been lost over the past century, which represents a net loss of roughly 32.2 percent of Alberta's forest (trees and vegetation only) carbon stocks. This amount represents only a portion of the total forest carbon loss; for example, it does not include the important below-ground carbon pools (e.g., soils, peatlands, wetlands). Based on the most recent global carbon value estimates of C$38.60 per tonne by Sara Wilson and Mark Anielski (based on Stern, 2006) the loss of the forest carbon capital alone in Alberta during the past 100 years would equate to a $9.6 billion loss.

Although the benefits of land uses are frequently computed, discussed, and presented to Canadians, there is an embarrassing absence of dialogue concerning the economic role of natural capital. Further, the erosion of capacity for ecological services is seldom understood when stakeholders are confronted with new land-use development opportunities. A reasoned approach to socio-economic sustainability of land uses demands that economists reformulate their "economic" indices in a way that properly expresses the full suite of associated economic benefits and risks.

Wetlands near Willow Lake Duck Banding Station, Mackenzie Valley, NWT, August 2005
Garth Lenz

Norman Wells,
Mackenzie Valley, NWT,
August 2005
Garth Lenz

Appendix: Detailed Mackenzie Ecosystem Service Product Value Estimates

Source of analysis	Barren Land (Tundra/Permafrost)	Burns	Cropland	Deciduous Broadleaf, temperate forest	Evergreen Needleleaf, temperate forest	Grass / rangelands
	Use peatland as proxy value adjusted for relative depth of permafrost vis-à-vis peat depth	50% of boreal temperate values (Wilson/Anielski) as proxy	Costanza, food production value removed	Wilson/Anielski BEWAS	Wilson/Anielski BEWAS	Costanza
Area (ha) by land type	25,031,600	8,719,600	3,437,200	420,700	62,926,800	33,200
Ecosystem Service Functions						
1. Atmospheric regulation	$ –	$ –		$ –	$ –	$ 10.55
2. Climate regulation	$ 3,946.15	$ 308.05		$ 616.11	$ 616.11	$ –
3. Disturbance avoidance	$ –	$ –		$ –	$ –	$ –
4. Water stabilization and regulation	$ –	$ –		$ –	$ –	$ 4.52
5. Water supply		$ 0.06		$ 0.11	$ 0.11	$ –
6. Erosion control and sediment retention		$ –		$ –	$ –	$ 43.72
7. Soil formation	$ –	$ –		$ –	$ –	$ 1.51
8. Nutrient cycling	$ –	$ –		$ –	$ –	$ –
9. Waste treatment	$ –	$ –		$ –	$ –	$ 131.17
10. Pollination	$ –	$ –	$ 31.82	$ –	$ –	$ 37.69
11. Biological control	$ –	$ 12.98	$ 54.56	$ 25.97	$ 25.97	$ 34.68
12. Habitat/Refugia		$ 0.32		$ 0.63	$ 0.63	$ –
13. Food production		$ 1.27		$ 2.55	$ 2.55	$ 101.02
14. Raw materials		$ –		$ –	$ –	$ –
15. Genetic resources		$ –		$ –	$ –	$ –
16. Recreation		$ 9.27		$ 18.53	$ 18.53	$ 3.02
17. Culture	$ –	$ 0.80		$ 1.60	$ 1.60	$ –
Total per ha $/ha/yr	$ 3,946	$ 333	$ 86	$ 666	$ 666	$ 368
Total 'potential' global ESP value$millions/yr	$ 83,765	$ 2,901	$ 297	$ 280	$ 41,878	$ 12
Total gl*obal ESP* value value $/ha/yr						

Note: Many ecosystem service values have not been accounted for in this study primarily because no data exist at the time of this study that are relevant to the Mackenzie watershed. Blank spaces in this table do not imply that ecosystem service values do not exist; rather, more research is required to complete a full value accounting.

Mixedwood	Mosaic Land (cropland + native vegetation)	Snow & Ice	Transition Treed Shrubland (Closed and Open shrubland)	Urban & Built-up	Wetlands & Peatlands Water	bodies (lakes and rivers)	Total all Land-cover Values
Boreal temperate value as proxy	Cropland values as proxy	not valued but glaciers would have equivalent value to water bodies	Similar to Burn	Assumes 90% loss of cropland (40%), water bodies (10%), mixed wood services (50%)	Wilson/Anielski BEWAS	Costanza	
23,818,600	2,660,600	720,400	15,226,800	5,700	27,199,400	12,275,500	
$ –	5.28		$ –	$ –	$ –	$ –	$ 14
$ 616.11	–		$ 308.05	$ 277.25	$ 3,946.15	$ –	$ 252,180
$ –	–		$ –	$ –	$ –	$ –	$ –
$ –	2.26		$ –	$ 738.85	$ –	$ 8,209.43	$ 100,785
$ 0.11	–		$ 0.06	$ 287.31	$ 555.00	$ 3,191.80	$ 54,289
$ –	21.86		$ –	$ –	$ –	$ –	$ 60
$ –	0.75		$ –	$ –	$ –	$ –	$ 2
$ –	–		$ –	$ –	$ –	$ –	$ –
$ –	65.59		$ –	$ 90.24	$ –	$ 1,002.62	$ 12,487
$ –	34.76		$ –	$ 11.46	$ –	$ –	$ 203
$ 25.97	44.62		$ 12.98	$ 31.33	$ –	$ –	$ 2,882
$ 0.63	-		$ 0.32	$ 0.28	$ 335.03	$ –	$ 9,175
$ 2.55	50.51		$ 1.27	$ 6.71	$ 75.01	$ 61.82	$ 3,189
$ –	–		$ –	$ –	$ 23.34	$ –	$ 635
$ –	–		$ –	$ –	$ 356.70	$ –	$ 9,702
$ 18.53	1.51		$ 9.27	$ 10.01	$ 18.53	$ 18.53	$ 2,573
$ 1.60	–		$ 0.80	$ 0.72	$ –	$ –	$ 159
$ 666	$ 227		$ 333	$ 1,454	$ 5,310	$ 12,484	$ 2,631
$ 15,851	$ 604	$ –	$ 5,067	$ 8	$ 144,422	$ 153,250	$ 448,336
							$ 2,631.25

Endnotes

1 www.dehchofirstnations.com/resource_management/index.html retrieved 2007-01-16.

2 United Nations. 2005. The Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003 (SEEA 2003). Available at unstats.un.org/unsd/envAccounting/seea.htm, accessed 2007-01-16.

3 Alberta Municipal Affairs. 2006. *2006 Official Population List*. Ft. McMurray is part of the special municipality known as the Regional Municipality of Wood-Buffalo.

4 Google Earth, retrieved on 2007-01-16.

5 Ibid.

6 Statistics Canada, Community Profiles. Census 2001 data. Retrieved on 2007-01-16 http://www12.statcan.ca/english/profil01/CP01/Search/SearchForm_Results.cfm?Lang=E

7 Cizek, Petr. 2005. Choice of Futures: Cumulative Impact Scenarios of the Mackenzie Gas Project. Report prepared for the Canadian Arctic Resources Committee. October 24, 2005. pgs. 43-44. Cizek's report conducts various cumulative impact analyses based on various natural gas pipeline development scenarios and concludes: "Total linear corridor density (roads, pipelines, and seismic cut-lines) exceeds the extirpation threshold for woodland caribou (3.0 linear km/sq km) in the Mackenzie Delta (onshore) both above and below the tree-line in all scenarios." And that "Existing seismic cut-lines may have already reached the cautionary threshold for woodland caribou (1.0 linear km/sq km)."

8 Barbajosa, Alejandro (18 Feb 2005). *Shell, Exxon Tap Oil Sands, Gas as Reserves Dwindle*. Retrieved on 2007-01-16 at www.energybulletin.net/4385.html

9 Sproule Associates Ltd. 2005. *Natural Gas Resource Assessment and Deliverability Forecasts, Beaufort-Mackenzie and Selected Northern Canadian Basins*, May 2005.

10 These estimates of average producer sales per unit of natural gas production in Canada are based on Canadian Association of Petroleum Producer statistics for 2005; producer sales divided by total natural gas production.

11 Canadian Association of Petroleum Producers. Fast Facts Alberta's Oil and Gas Industry available at http://www.oilandgasinalberta.ca/fastFacts.asp retrieved 2007-01-16.

12 Analysis for the Mackenzie based on G.C. Daily and K. Ellison, *The New Economy of Nature: The Quest to Make Conservation Profitable* (Washington, D.C.: Island Press, 2003), pp. 2-5; New York City Department of Environmental Protection, New York City 2005 Drinking Water Supply and Quality Report (2006), www.nyc.gov/html/dep/pdf/wsstat05.pdf (retrieved 2007-01-16).

13 World Bank. *Where is the Wealth of Nations?*(2006), p.159.

14 Paul C. Sutton and Robert Costanza. "Global Estimates of market and non-market values derived from satellite imagery, land cover, and ecosystem service valuation," *Ecological Economics* 41 (2002):517.

15 Paul C. Sutton and Robert Costanza, "Global Estimates of market and non-market values derived from satellite imagery, land cover, and ecosystem service valuation." *Ecological Economics* 41 (2002):517; Christopher N.H. Doll, Jan-Peter Muller, Jeremy G. Morley, "Mapping regional activity from night-time light satellite imagery," *Ecological Economics* 57 (2006):75-92; Paul C. Sutton, "An Empirical Environmental Sustainability Index Derived Solely from Nighttime Satellite Imagery and Ecosystem Service Valuation," *Population and Environment* 24, no. 4 (2003).

16 Light Emission using Category #5, which is the brightest 25% of total light emissions, were mapped and hectares of LE5 were estimated.

17 Based on Anielski Management Inc. calculations of GDP in the cities of Leduc, Calgary and Edmonton, in Mark Anielski, *Alberta Region's 2005 Genuine Well-being Report* (May 2006).

18 Paul C. Sutton and Robert Costanza, "Global Estimates of market and non-market values derived from satellite imagery, land cover, and ecosystem service valuation," *Ecological Economics* 41 (2002):509-527.

19 The carbon stored in peatlands and tundra was calculated based on an average depth of 2.2 m, mean bulk density of 112 g/L, and carbon content of 51.7% of dry biomass. Source: E. Gorham, "Northern Peatlands: Role in the Carbon Cycle and Probable Responses to Climatic Warming." *Ecological Applications* 1(1991):182-195. The carbon stored in forest biomass and soil was calculated using the approach used in M. Anielski and S. Wilson, *Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems* (The Canadian Boreal Initiative and the Pembina Institute, 2005).

[20] Ecosystem services taxonomy was developed by Amanda Sauer, *The Values of Conservation Easements*, discussion paper, World Resources Institute, presented to West Hill Foundation for Nature (December 1, 2002) and values for ecosystem services estimated by 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): 253–259.

[21] Valuation methods are based on several sources, including Costanza et al. (1997), Anielski and Wilson (2005) in the Boreal Wealth Accounting study, *Counting Canada's Natural Capital*, and new values estimated for this study.

[22] Roughly 173,900 hectares of the Mackenzie is glaciated, representing 24% of the snow and ice land-cover area.

[23] The individual GDP estimates for forestry, mining, oil, gas and agricultural sectors do not add up to the total GDP for the Mackenzie region since the total GDP includes economic activity from other sectors.

[24] The estimated ecological service values for barren land or tundra are based on valuation of only the portion of tundra which is known as permafrost; there are 21,227,108 hectares of permafrost which are valued at $3,946/ha, primarily because of the value of stored carbon.

[25] Roughly 173,900 hectares of the Mackenzie is glaciated representing 24% of the snow and ice land-cover area.

[26] Satellite images were the main source of data. 1,037 Landsat images were used, mostly from the summer season, 1985 to 2003. This imagery was the primary data source for the manual exclusion of anthropogenic disturbances. Landsat 5(TM) and Landsat 7 (ETM+) imagery were chosen because of their resolution (28.5 metres) and the availability of several spectral bands. Almost all of the Landsat images used in the study had less than 10 percent cloud cover. The majority of the images were orthorectified by NASA (and/or the Earth Satellite Corporation). Orthorectified Landsat data was made publicly available by NASA on December 23, 2003. The products available include Landsat Enhanced Thematic Mapper (ETM+), Pansharpened ETM+, and Thematic Mapper (TM) data from the Landsat 4, 5 and 7 missions. The data was compiled through NASA's Commercial Remote Sensing Program, which is a cooperative effort between NASA and the commercial remote sensing community to provide users with access to quality-screened, medium resolution satellite images with global coverage over the Earth's land masses. The Landsat (TM) dataset contains orthorectified Landsat (TM) sensor data from the Landsat 4 and 5 satellites. Landsat (TM) data was orthorectified by NASA using the best available geodetic and elevation control data to correct for positional accuracy and relief displacement. Landsat 7 (ETM+) data was orthorectified using the orthorectified Landsat TM data. The result of the orthorectification process is a final image map product with a Root Mean Square Error (RMSE) of better than 50 metres (2 pixels) in positional accuracy.

Areas associated with the following main types of human disturbances were excluded. These areas were excluded only if positive signs of disturbance could be detected in satellite images.

Areas affected by land use in addition to those noted above:

- roads of all types;
- railroads;
- seismic and other cutlines clearly visible in satellite images;
- power lines and communication lines, assuming there was clearing of vegetation along the lines;
- pipelines;
- recently completely anthropogenically converted areas, such as settlements;
- built-up populated and industrial areas;
- croplands (both current and abandoned); and
- reservoirs.
- clearcuts;
- all types of mining and drilling activity areas; and
- other areas affected by industrial activity.

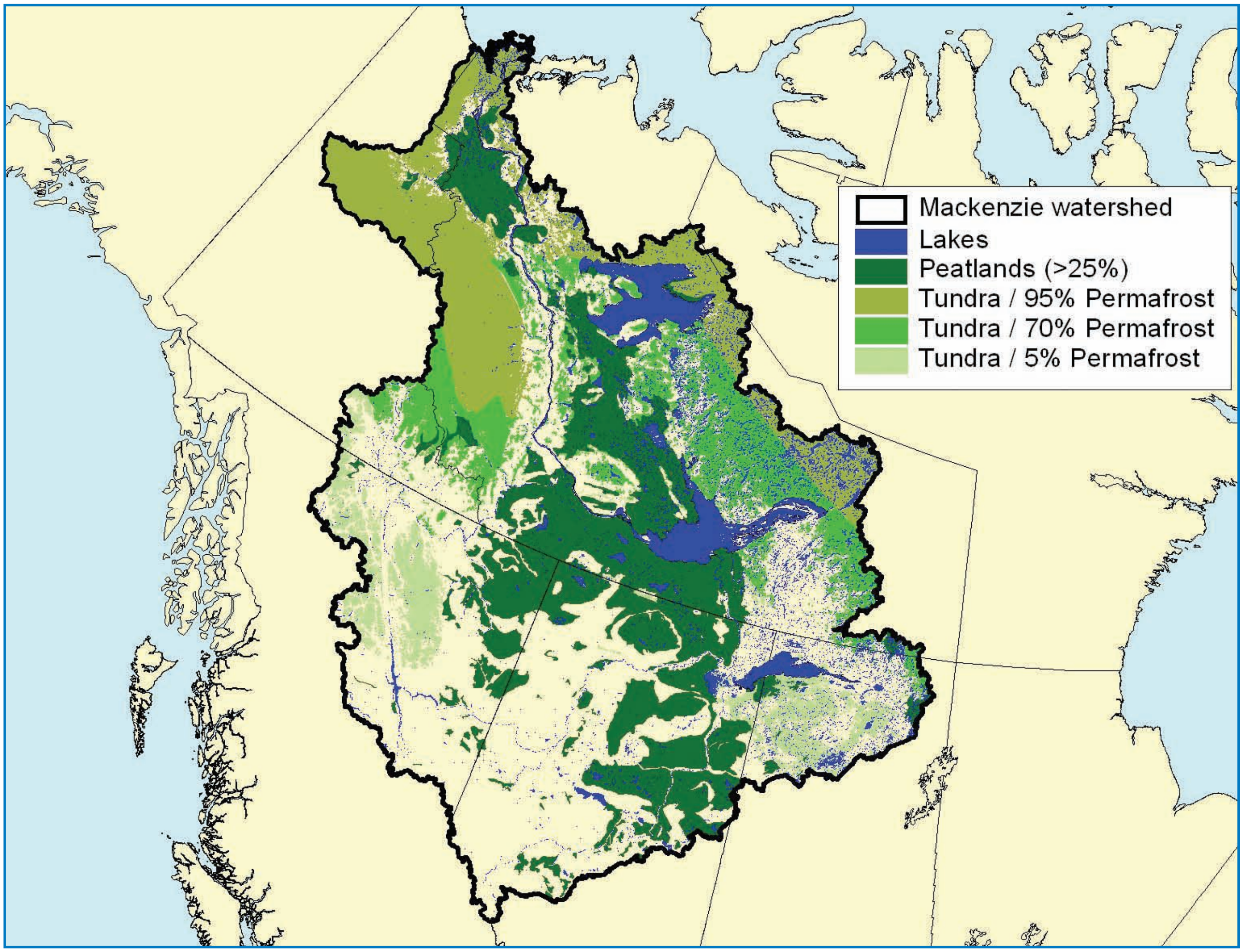
After one interpreter completed the visual interpretation of disturbances, a second interpreter checked the accuracy of the mapping at the same scale. Questionable areas were highlighted, checked and, where necessary, corrected by a third interpreter using a variety of scales and image dates. Areas of uncertainty were resolved through discussion within the interpretation team and by the use of ancillary data.

A combination of field checks, aerial photo checks, and expert review was conducted to verify the draft map of forest landscape fragments.

All anthropogenic disturbances were mapped and buffered by 500 metres on each side. This buffering was made to accommodate an ecological footprint and to accommodate some orthorectification challenges.

Boreal ecosystems store more carbon in their peatlands, soils and trees than any other land-based ecosystem, including tropical rainforests. The carbon values in the Mackenzie watershed are immense and in particularly high concentrations in all of the green shaded ecotypes on this map. In this study, the carbon values alone added up to 56 percent of the total estimated non-market value of all ecosystem services in the watershed.

Source: Global Forest Watch Canada



Conclusions and Recommendations

This study shows that the natural capital of the Mackenzie Region contributes significantly to the cultural, social and economic health and well-being of all Canadians. The full wealth of the Mackenzie is significantly discounted when measured only in terms of market value. By not considering the economic value of our natural capital assets – clean air, clean water, and healthy, productive landscapes—in our economic calculus, we are missing an opportunity to account for what most Canadians agree are our most important national assets.

This study provides estimates and perhaps more importantly, describes methods by which natural capital accounts can be developed on a regional scale. As the practice of natural capital accounting is in its infancy, our findings must be considered preliminary. Further work in this area is required to more fully describe natural capital values and to accurately track and measure changes in ecosystem values over time.

To further natural capital accounting and management, we recommend that:

1. Comprehensive inventories of natural capital values be undertaken at national, provincial, territorial and regional scales, and that this information be maintained in a current state and made publicly available;

2. Research be undertaken to better understand the relationship between industrial development and natural capital, and that active monitoring of the pace, scale and extent of anthropogenic changes in the landscape be undertaken in order to determine the impacts of human-induced development on the economic value of ecosystem services.

3. Consistent values and methods for natural capital accounting be adopted on a national basis to guide resource and land-use planning decisions.

4. Decision makers move much more actively to safeguard areas of where natural capital values, such as those related to water quantity and quality and carbon storage and sequestration, can be secured across Canada's boreal region for the benefit of current and future generations. Such measures can be effectively implemented through land-use planning in advance of major development and through an expanded network of parks and protected areas. The balanced approach embodied in the Dehcho Land Use Plan provides an example of how this could be achieved by drawing on both science and traditional knowledge to guide development decisions.

5. That innovative mechanisms be explored to integrate natural capital values into market-value economics and sustainable development practices. Regulatory and voluntary carbon trading regimes are an example of efforts to ensure that climate-related costs are effectively integrated into market decisions. Similar regimes should be considered for clean water and other natural capital assets to ensure that economic activities reflect the full costs and benefits to society. Particular priority should be given to innovation in the private sector to take nature more fully into account.

Cover map source: World Resources Institute
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