Natural Capital in BC's Lower Mainland

VALUING THE BENEFITS FROM NATURE

David Suzuki Foundation

SOLUTIONS ARE IN OUR NATURE

Pacific Parklands FOUNDATION

A Foundation for the Future of Our Parks

NATURAL CAPITAL IN BC's LOWER MAINLAND: VALUING THE BENEFITS FROM NATURE

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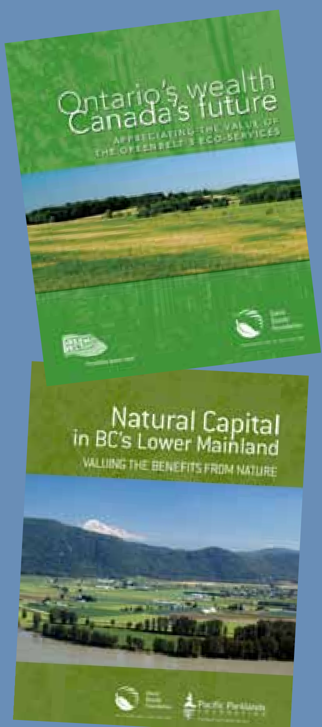

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Foreword

WE OFTEN TAKE FOR GRANTED the astonishing array of benefits that nature provides. Trees clean our air and wetlands filter our water. Forests absorb carbon, thereby acting as a "hedge" against climate change, and green urban spaces cool our cities and protect us from storms. And this doesn't even account for the health and spiritual benefits people receive from time spent in nature. It is increasingly clear that the health of our families and our communities depends on the health of the ecosystems that surround us.

The ecosystems that provide these benefits are often referred to as *natural capital* – the fields, farms, forests, wetlands, and rivers within and surrounding our communities. Research by the David Suzuki Foundation and others has shown that natural capital, and the benefits it provides, are extremely valuable in monetary terms, and in reality they are truly priceless.

Research by the David Suzuki Foundation and others has shown that natural capital – the fields, farms, forests, wetlands, and rivers within and surrounding our communities – and the benefits it provides, are extremely valuable in monetary terms, and in reality they are truly priceless.

Rapid population growth and extensive development in all major Canadian urban centres are placing unprecedented pressure on our natural capital, leading to the degradation and loss of farms, fields, forests, wetlands, and estuaries. According to the experts, more than half of the original wetlands in the Lower Mainland and 90 per cent of Garry oak meadows on southeastern Vancouver Island and the southern Gulf Islands have been lost to human development. As a consequence these regions are now hotspots of endangered species in the province.

However, programs to protect, restore and enhance natural capital are gaining support in Canada and abroad and can be a wise investment for our cash-strapped cities. For example, in the early 1990s New York City chose to invest in a comprehensive program to protect its watershed through land purchase, pollution control and conservation easements, rather than build new infrastructure to filter its water. In doing so, the city has saved billions of dollars in avoided costs and the watershed continues to provide clean drinking water without the need for filtering.

In Canada, the establishment of "greenbelts" of protected forests, agricultural lands, wetlands, and other green spaces around cities like Toronto and Ottawa has helped to protect essential ecosystem services, like water filtration and wildlife habitat. The benefits provided by southern Ontario's Greenbelt alone have been conservatively estimated at $2.6 billion annually.

Over the past twenty years we at the David Suzuki Foundation have learned a lot about the benefits of reconnecting people with nature in their communities, and encouraging them to learn more about the many benefits nature provides. It is our hope that reports like this one will help to cultivate a deeper appreciation of the true value of nature and ensure that the vital green spaces within and around our communities are protected, restored and enhanced.

— Dr. Faisal Moola
Director of Terrestrial Conservation and Science, David Suzuki Foundation
Adjunct Professor, Faculty of Forestry, University of Toronto

Accompanying this report are images taken by contributors to David Suzuki's Nature in the City Photo Contest. Thanks to all for your contributions.

PHOTO COURTESY TAMI KOLKE

ACKNOWLEDGEMENTS

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Thanks to Heather Wornell and David Major of Metro Vancouver for their support and for the wetland data analysis that they have shared. Many thanks to Mark Anielski, Josephine Clark and Mike Kennedy for the time they took to provide comments for the final report.

Special thanks to Peter Lee, Matt Hanneman and Ryan Cheng of Global Forest Watch Canada for their invaluable skills in spatial data analysis and mapping that makes this type of project possible.

DISCLAIMER

This study should be considered a preliminary and coarse-scale natural capital account for the Lower Mainland and its watersheds. It is a first step towards a more comprehensive accounting of natural capital assets in the region that provides a framework for similar studies across Canada. More Canadian research is needed to determine a full range of ecosystem service values relevant to Canadian ecoregions and landcover types. This work is intended to encourage others to consider the value of natural capital and its ecosystem services, as well as to stimulate a growing dialogue regarding the real value of natural capital, ecosystem services, stewardship and conservation.

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

Every effort to ensure the accuracy of the information contained in this study has been taken, however, peer review was limited by time constraints. We welcome suggestions for improvements that can be incorporated into later editions of this study.

Executive Summary

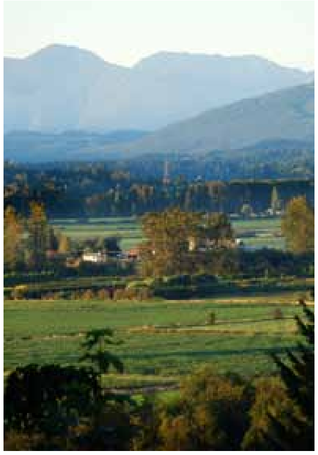
IT IS EASY TO FORGET THAT NATURE is the source of such necessities as the food we eat, air we breathe and water we drink. Nature's ecosystems also provide less plainly obvious services such as protecting us from floods and storms or pollinating our plants. These and other benefits have supported extraordinary growth of the human population throughout the world. Yet a majority of our ecosystems are in serious decline, especially ones near our sprawling towns and cities. Thus it is increasingly apparent that nature's benefits can no longer be taken for granted. Ignoring the health of our ecosystems and the essential benefits they provide threatens our way of life.

This report examines the extent of natural capital – the forests, fields, wetlands and waterways – in British Columbia's lower mainland region, and estimates the non-market economic values for the various services and benefits these ecosystems provide. We often do not recognize these benefits or pay directly for these services, so they are undervalued in our market economy. The intent of this report is to provide a preliminary assessment of ecosystem services in economic terms so decision makers and the public can appreciate the true cost of degrading our ecosystems and, conversely, the potential economic benefits of protecting and restoring the region's wealth of natural capital.

BC's Lower Fraser Valley contains some of Canada's best agricultural lands, wetlands and forests. However urbanization and development continues to result in the loss of natural capital across this region. The population of the region including the Greater Vancouver Regional District and the Fraser Valley District has grown quickly over the past two decades. In 2007, approximately 57 per cent of British Columbia's population resided in the Lower Mainland region. The population is now over 2.5 million people, and it is estimated to grow to over 3 million by year 2020, thus potentially placing enormous stress on the region's natural capital and ecosystem services.[1]

Urbanization and development in the Lower Mainland is resulting in the loss of some of Canada's best agricultural lands, wetlands, and forests.

PHOTOS COURTESY (ABOVE) SHERWOOD PATRICK AND (BELOW) NADENE REHNBY



1 BCStats. 2009 *Municipal Population Estimates*.

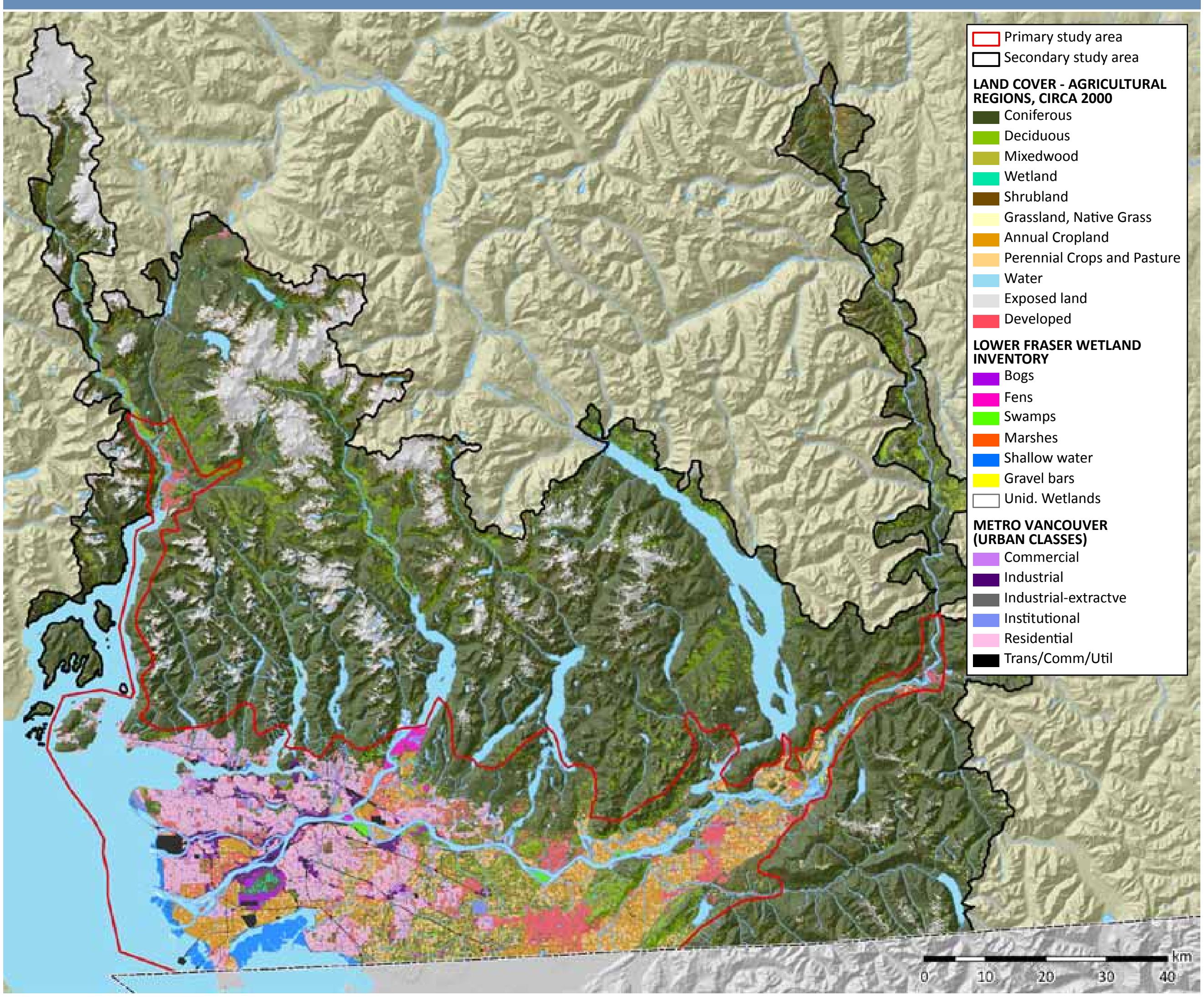
This report was commissioned by the Pacific Parklands Foundation to determine the non-market benefits provided by the natural capital within B.C.'s Lower Mainland and its watersheds. Two nested study areas were selected: the primary area is the "Lower Mainland" from Hope in the east to Squamish; and, the secondary study area includes the upper watersheds. Several existing databases were used to create a land cover database for the study area.

Our land cover analysis indicates that in the entire study area, the dominant ecosystem type is forests at 61 per cent. Urbanized or developed lands cover 9 per cent of the lands, including 27 per cent of the primary study area. Alpine or exposed lands cover 10 per cent, while water covers 9 per cent of the region. Shrublands/grasslands and agricultural lands cover approximately 5 per cent each. Wetlands cover 2.4 per cent of the total study area.

Forests are the dominant land-cover/use in the study region, followed by urbanized or developed land.

The potential ecosystem services and the economic benefits these ecosystems provide were ascribed to the various land cover types where possible. The valuations were established based on analyses of regional data and local studies, as well as regional and global economic information. Valuations were predominantly cost-based estimates, such as the cost of avoided damages or the cost to replace a particular service.

STUDY AREA LAND COVER AND LAND USE



The top three benefit values provided by the study area's ecosystem services are: (1) climate regulation resulting from carbon storage by forests, wetlands, grasslands, shrublands and agricultural soils; (2) water supply due to water filtration services by forests and wetlands; and (3) flood protection and water regulation provided by forest land cover. It is estimated that climate regulation provides an estimated value of $1.7 billion per year, while water supply provides an estimated $1.6 billion per year, and flood protection and water regulation provides an estimated $1.2 billion per year.

The other values determined for the study area include the following benefits: clean air, waste treatment, pollination, salmon habitat, recreation, and local food production. The total value for all benefits provided by the study area's natural capital is an estimated $5.4 billion per year or about

The top three benefit values from the study area's ecosystem services are climate regulation ($1.7 billion per year), water supply ($1.6 billion) and flood protection/ water regulation($1.2 billion).

STUDY AREA LAND COVER AND LAND USE

Land cover class	Primary study area (hectares)	Per cent of primary area	Total study area (hectares)	Per cent of total area
Residential	50,900	11.7%	51,278	3.8%
Commercial	4,274	1.0%	4,275	0.3%
Industrial	7,156	1.6%	7,156	0.5%
Industrial-extraction	540	0.1%	540	0.0%
Institutional	5,201	1.2%	5,202	0.4%
Transportation/commercial/utilities	8,176	1.9%	8,253	0.6%
Fens	2,448	0.6%	2,448	0.2%
Bogs	1,933	0.4%	1,934	0.1%
Marshes	2,960	0.7%	3,132	0.2%
Swamps	1,722	0.4%	1,722	0.1%
Shallow water wetlands	11,809	2.7%	11,924	0.9%
Gravel bars	3,477	0.8%	3,485	0.3%
Unknown wetlands	1,470	0.3%	2,391	0.2%
Other wetlands	1,668	0.4%	5,181	0.4%
Water	75,573	17.4%	121,145	8.9%
Exposed land	3,178	0.7%	131,104	9.6%
Developed	41,963	9.6%	43,935	3.2%
Shrubland	8,339	1.9%	61,387	4.5%
Grassland, native grass	45	0.0%	5,150	0.4%
Annual cropland	30,318	7.0%	30,519	2.2%
Perennial crops and pasture	31,656	7.3%	31,847	2.3%
Coniferous	104,469	24.0%	722,433	53.1%
Deciduous	35,369	8.1%	99,651	7.3%
Mixed forest	293	0.1%	3,787	0.3%
Total area	434,937	100.0%	1,359,878	100.0%

The total value for all benefits provided by the study area's natural capital is an estimated $5.4 billion per year – or about $2,462 per person, per year, for those living in the region.

VALUE OF ECOSYSTEM SERVICES BY BENEFIT (2005$)

Benefits	Land cover type	Total value millions$	Value per hectare ($/ha)
Climate regulation	Forests (primary study area)	$246	$1,709
	Forests (secondary study area)	$1,280	$1,898
	Wetlands	$44	$1,432
	Grasslands	$3.1	$594
	Shrublands	$61	$1,000
	Croplands	$41	$698
Clean air	Forests	$409	$495
Coastal protection	Marshes	n/a	n/a
Flood protection/ water regulation	Forests	$1,241	$1,502
Waste treatment	Wetlands	$41	$1,283
Water supply	Forests	$1,561	$1,890
	Wetlands	$61	$1,890
Pollination	Forests (primary study area)	$234	$1,669
	Shrublands (primary study area)	$14	$1,669
	Grasslands (primary study area)	$0.1	$1,669
Salmon habitat	Integral forests	$1.6	$3
Recreation/tourism	Forests	$105	$127
	Wetlands	$4.1	$127
	Farm-based	$13	$422
Local food production	Croplands	$24	$382
Total		$5,384	

$3,959 per hectare.[2] This equates to an estimated value of $2,449 per person or $6,368 per household each year, based on statistics from the 2006 census.[3]

Net present values are commonly used to assess the economic benefits of investment for decision-making. Net present values were assessed with three different discount rates. A zero discount rate represents the fact that natural capital does not depreciate over time; a 3 per cent discount rate is commonly used in socio-economic studies, and a 5 per cent discount rate is a more conventional rate. Over a 50-year period, the net present value is $270 billion at 0 per cent discount rate, $139 billion at a 3 per cent discount rate, and $96 billion at a 5 per cent discount rate.

2 2006 census data was extracted for the study area. The results show that 2,194,377 in the primary study area, and the combined population for primary and secondary areas is 2,197, 918.

3 Analysis of the 2006 census reports that 2.2 million people live within the study area Number of households is estimated based on total population from 2006 census, assuming that there are approximately 2.6 people on average per household.

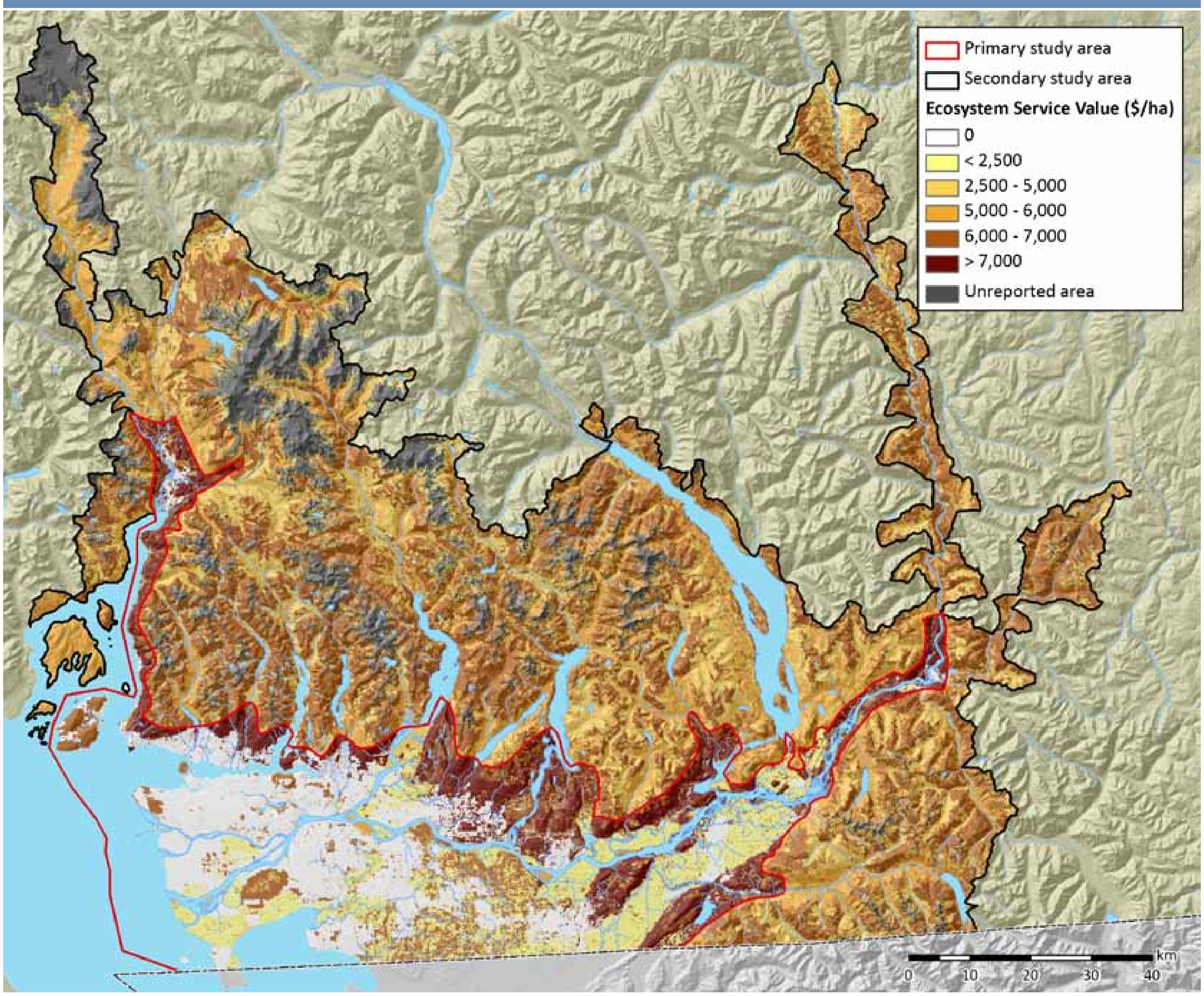
NET PRESENT VALUES FOR ECOSYSTEM BENEFITS (2005$)

Discount rate	Net present value (50-year period) billions$	Value per capita	Value per household
0%	270	$122,844	$319,393
3%	139	$63,242	$164,428
5%	96	$43,678	$113,562

The distribution of ecosystem benefits across the study area was determined using the average values at the landscape and watershed level. The average annual values across the study area range from $0 to greater than $7,000 per hectare. The values are highest for the immediate watershed areas above Metro Vancouver and the Fraser Valley, as well as the wetlands within the Fraser Valley lowlands. The lowest values are the developed areas of Metro Vancouver and within the primary study area. The upper watersheds vary in value based on forest age and respective carbon storage.

By watershed, the values are highest for the immediate watershed areas above Metro Vancouver and the Fraser Valley.

AVERAGE ANNUAL ECOSYSTEM VALUES PER HECTARE

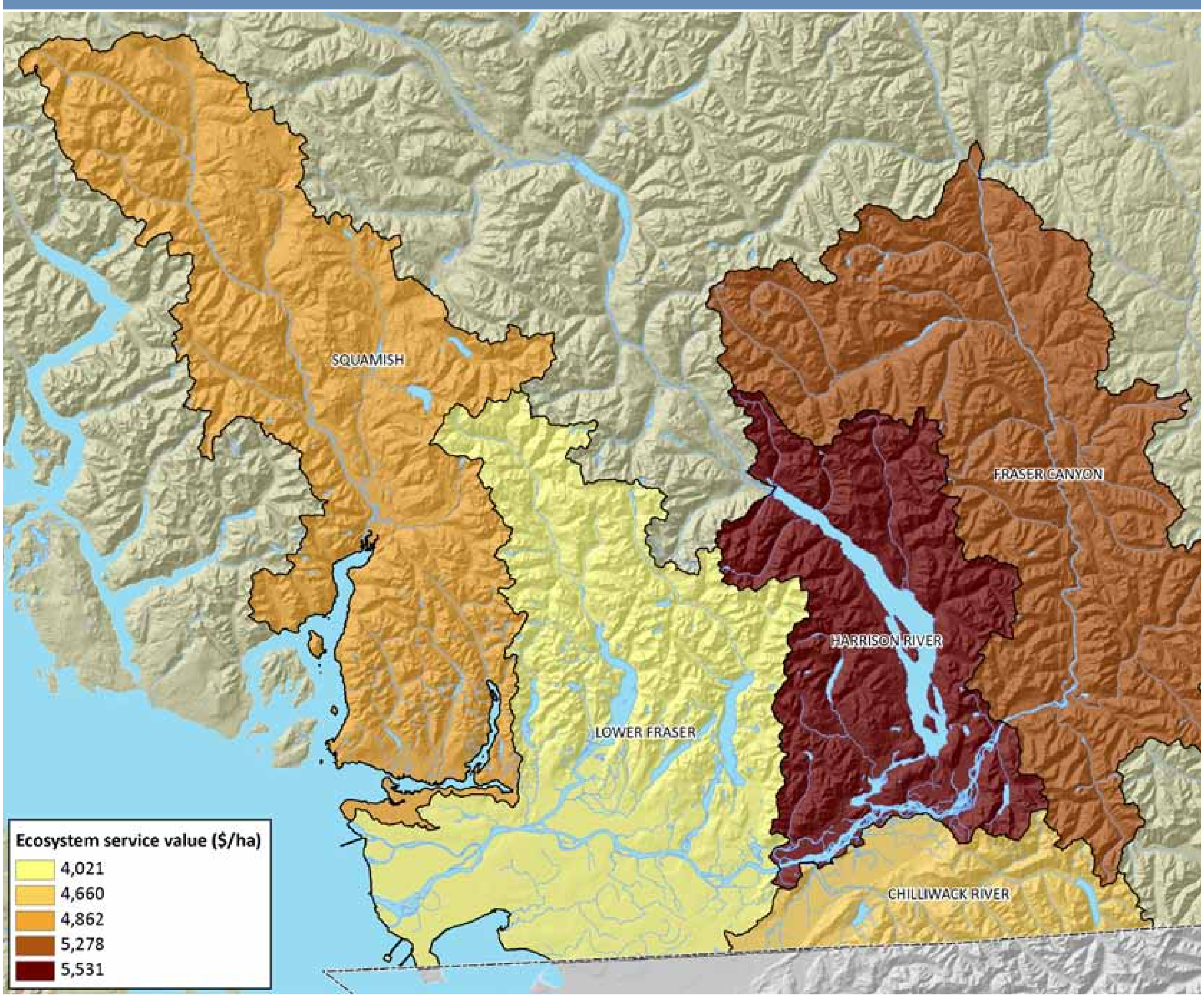


Average values were also assessed for five major watersheds within the study area. Harrison River watershed had the highest annual value estimated at $5,531 per hectare, followed by the Fraser Canyon watershed ($5,278 per hectare), the Squamish watershed ($4,862 per hectare), the Chilliwack River watershed ($4,660 per hectare), and the Lower Fraser ($4,021 per hectare). Average values per hectare were also assessed for community watersheds. The average value per hectare by community watershed was an estimated $6,434. Metro Vancouver's community watersheds showed average values just below the average. Seymour community watershed had an estimated $5,910 per hectare, and the Capilano community watershed showed an estimated $5,819 per hectare, based on the average values by land cover type.

It is our hope that this preliminary assessment will stimulate discussion about how we value – and undervalue – natural capital in and around our cities.

This report for the first time quantifies the economic benefits provided by the vast wealth of natural capital in the watersheds of the Lower Mainland. It is our hope that this preliminary assessment will stimulate discussion about how we value – and undervalue – natural capital in and around our cities. We encourage decision makers and the public to use this report, and other natural capital valuations, to inform discussion on how to best protect and restore the region's precious natural capital and ensure a sustainable future.

AVERAGE ANNUAL ECOSYSTEM VALUES BY WATERSHED GROUP



PART 1

Introduction

WHAT IS NATURAL CAPITAL?

Natural capital refers to the earth's land, water, atmosphere and resources. This capital is organized and bundled within the earth's natural ecosystems, which provide resources and flows of services that enable all life to prosper on earth. In Canada, this natural capital is critical to the economic and social well-being of Canadians. Our landscapes consist of forests, wetlands, grasslands and rivers that act like giant utilities providing ecological services for local communities as well as regional and global processes that we all depend upon.

Ecosystems provide a plethora of services including the storage of flood waters, water capture and filtration, air pollution absorption by trees and climate regulation resulting from carbon storage in trees, plants and soils. However, as we do not pay directly for these services, they are undervalued in our market economy. It Is estimated that they are worth trillions of dollars per year, yet they are not monitored, measured nor accounted for in decision-making and land use planning.

While Canadians recognize the importance and value of the environment to their well-being, the conditions and values of Canada's natural capital assets are not accounted for in measures of economic progress like the Gross Domestic Product (GDP) or in Canada's national accounts. Although Statistics Canada has established satellite accounts for marketable products such as timber and potash, Canada's most important assets (natural capital) are generally not measured or accounted for.

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WHY IS IT IMPORTANT TO MEASURE NATURAL CAPITAL?

Human life itself depends on the continuing ability of the natural environment to function and provide its many benefits. Yet, economic development generally focuses on what we can take from the environment.[4] It is essential that natural capital is identified, measured and monitored because without proper accounting natural capital will continue to be undervalued and will continue to

4 White, R.P., Murray, S., and Rohweder, M. 2000. *Pilot Analysis of Global Ecosystems: Grassland Ecosystems*. World Resources Institute. Washington, D.C. (www.wri.org/wr2000)

decline. The loss of natural capital has massive economic impacts that threaten our health and the stability of our climate.

Further declines in natural capital are predicted if business and communities continue along the same path of economic growth without accounting for their impact on the environment and its true costs. Currently, economic gains resulting from human activities that deplete natural capital do not include the real costs and therefore do not have to be paid. There is growing concern that if the costs of damage to the environment continue to go unpaid by the private sector and consumers, then the loss and damage to the environment will continue creating crises in the form of pollution and the rapid loss of fresh water, fisheries and fertile soils.

According to a report for the United Nations Environmental Program Finance Initiative (UNEP FI), the cost of pollution and other damage to the natural environment caused by the world's 3,000 largest companies is equal to one-third of their profits if they were to pay the full costs for the use, loss and damage to the environment. The study found that the estimated combined environmental damages added up to US$2.2 trillion in 2008 – a figure larger than the national economies of all but seven countries in the world that year.[5] The largest single impact was due to greenhouse gas emissions, which accounted for over half of the total costs. Other major costs include local air pollution such as the impacts of particulates and the damage caused by the over-use and pollution of freshwater.[6] In the same study, Trucost assessed the environmental costs of global human activity at US$ 6.6 trillion in 2008, equivalent to 11 per cent of global Gross Domestic Product (GDP).[7] Their study projects that environmental costs will amount to US$28.6 trillion by 2050 (18 per cent of GDP) if "business as usual" continues.

The loss of natural capital has massive impacts that threaten health, food production, climate, and basic needs such as clean air and water.
PHOTO COURTESY PAUL HENMAN

THE IMPORTANCE OF VALUING ECOSYSTEM SERVICES

One of the main reasons for losses in natural capital is its exclusion from our current measures of value and decision-making. Values not reflected in market prices are considered externalities.[8] For example, the value of a forest or grassland in controlling stream-bank erosion and sediment load in a river is not reflected in the market price of land. Similarly, the costs of our impact on the environment, such as damages to due to pollution, are not taken into account. Therefore, decisions regarding the conversion of land for agriculture or urban development fail to account for the costs due to losses in natural capital.

The projected impacts of climate change will place additional pressure on our ecosystems. It is expected that it will compromise their ability to function and supply a stable flow of services such as water supply, flood control and pollination. Communities with less economic wealth and natural capital will find themselves struggling under the impacts of climate change. Since they will already be operating with reduced natural capital, some communities will be even more vulnerable to adverse and costly outcomes.

5 Jowit, J. "World's top firms cause $2.2tn of environmental damage, report estimates." *The Guardian*. February 18, 2010. (accessed May 2010) www.guardian.co.uk/environment/2010/feb/18/worlds-top-firms-environmenal-damage/print

6 This UN study is being carried out by Trucost, a London-based consultants firm and will be published in the summer of 2010.

7 Garfunkel, A. (ed.) 2010. *Universal Ownership: Why Environmental Externalities Matter to Institutional Investors*. Trucost Plc, PRI Association and UNEP Finance Initiative. www.unpri.org/files/6728_ES_report_environmental_externalities.pdf (accessed Sept. 2010)

8 An externality is a value that is not reflected in a commodity's market price.

Given the fundamental importance of natural capital to the sustainability of human communities, some economists are now reporting on the loss/degradation of natural capital in terms of the costs due to a reduction in critical ecosystem services.[9] For example, declines in the populations of bees, butterflies and other pollinators as a result of habitat destruction, pesticide use and invasive pests have been estimated to cost farmers millions of dollars each year in reduced crop yields.[10]

Communities and governments are beginning to recognize the essential ecosystem services that natural areas provide. The recognition and valuation of ecosystem services are emerging trends at the global, national and regional level. For example:

In 1997, a global study estimated the total value of the world's ecosystems goods and services to be worth between US$18 and $61 trillion (2000);[11] an amount similar to the size of the global economy.

A follow up study examined the economic trade-off of conserving natural areas and their ability to supply ecosystem services, rather than conversion for farming or urban land use. The study concluded that the net value of a hypothetical global reserve network would provide services worth approximately $4.4 trillion per year.[12] The study estimated that the rate of global habitat loss costs about $250 billion each year.

In 2005, the United Nations Millennium Ecosystem Assessment (MA) reported on the condition of the world's ecosystems and their ability to provide services[13] The MA found that over the past 50 years humans have changed the Earth's ecosystems more rapidly and extensively than in any other period in human history. The assessment concluded that approximately 60 per cent of the world's ecosystem services are being degraded or used unsustainably, including fresh water, air and water purification, and the regulation of regional and local climate.[14]The World Bank published an assessment of the natural capital market values for the world's nations.[15] Canada ranked third in terms of the country's per capita market value (timber, oil, gas, cropland, pasture land, non-timber forest products, and protected areas). This assessment did not include the non-market values of the services provided by Canada's natural capital, nor did it provide an assessment of the costs to natural capital from extraction, production and transportation of these products.

Two Canadian studies have assessed the economic value of natural capital for Canada's boreal region. The non-market value for the Mackenzie Region's natural capital has been estimated at $570 billion per year (an average of $3,426 per hectare), 13.5 times the market value of the region's natural resources.[16] The carbon stored by the Mackenzie watershed was estimated at a value of $339 billion ($820/ha/year).

Communities and governments are beginning to recognize the essential ecosystem services that natural areas provide. The recognition and valuation of ecosystem services are emerging trends at the global, national and regional level.

9 Perrings et al. 2006. "Biodiversity in agricultural landscapes: saving natural capital without losing interest." *Conservation Biology*. 20:263-264.

10 Tang, J., Wice, J., Thomas, V.G., and Kevan, P.G. 2007. "Assessment of Canadian federal and provincial legislation's capacity to conserve native and managed pollinators." *International Journal of Biodiversity Science and Management*. 3:46-55.

11 Costanza, R. et al. 1997. "The value of the world's ecosystem services and natural capital." *Nature*. 387:253-259.

12 Balmford, A. et al. 2002. "Economic Reasons for Conserving Wild Nature." *Science*. 297: 950-953.

13 www.millenniumassessment.org/en/Condition.aspx

14 Millennium Ecosystem Assessment. 2005. "Ecosystems and Human Well-being: Synthesis." Island Press. Washington, DC.

15 The World Bank. 2006. *Where is the Wealth of Nations?* World Bank. Washington, D.C.

16 Anielski, M., and Wilson, S. 2007. *The Real Wealth of the Mackenzie Region: Assessing the Natural Capital Values of a Northern Boreal Ecosystem*. (2009 Update). Canadian Boreal Initiative. Ottawa, Canada.

PREVIOUS REGIONAL VALUATION STUDIES

Two recent studies have undertaken surveys to assess the importance of having farmland in their community. In 2007, a case study in Abbotsford, B.C., by the BC Ministry of Agriculture and Lands surveyed Abbotsford residents on the value of the benefits provided by farmland in their community. The study found that the present value of the stream of public benefits and ecological services provided by each hectare of farmland was an estimated $29,490 per acre ($72,814 per hectare).[17] This value was estimated to be significantly greater than the value of public benefits from industrial land use ($14,000 per acre), or residential land use ($13,960 per acre).

A similar study was undertaken in 2009 to estimate the value of benefits provided by farmland in Metro Vancouver (formerly the Greater Vancouver Regional District). The study was based on a household survey and estimated for the public value of wildlife habitat and groundwater recharge. The results estimated that the value of farmland in Metro Vancouver was about $58,000 per acre per year; about 10 times greater than the market value of farm products ($5,750 per acre).[18] In 2008, Earth Economics undertook a study to assess the value of the goods and services provided by the Puget Sound Basin's natural capital. The Puget Sound is located south of the Lower Mainland in Washington State. The net present value for drinking water, food, wildlife, climate regulation, flood protection, recreation, aesthetic value among other ecosystem services was valued between $305 billion and $2.6 trillion (at a 3 per cent discount rate over 100 years).[19] The total area for the Basin is reported as 10.6 million acres (4.3 million hectares), so the net present value per hectare would be approximately $71,000 to $605,000 per hectare.

In Eastern Canada, two regional studies have assessed the non-market values of natural capital. One report quantified the value of the ecosystem services provided by southern Ontario's Greenbelt. This report estimated the value of the region's natural capital at $2.6 billion annually (average of $3,500 per hectare) and almost $8 billion since the Greenbelt was established.[20] A similar report for the Credit Valley Watershed reported that the watershed provides at least $371 million each year for the local residents.[21]

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17 *Public Amenity Benefits and Ecological Services Provided by Farmland to Local Communities in the Fraser Valley: A Case Study in Abbotsford, B.C*. 2007. Strengthening Farming Report. File Number 800.100-1. B.C. Ministry of Agriculture and Lands.

18 Robbins, M., Olewiler, N, and Robinson, M. 2009. *An Estimate of the Public Amenity Benefits and Ecological Goods Provided by Farmland in Metro Vancouver*. Fraser Basin Council and Simon Fraser University. B.C. Ministry of Agriculture and Lands.

19 Batker, D. and Kocian, M. 2010. *Valuing the Puget Sound Basin: Revealing our Best Investments*. Earth Economics. Tacoma, Washington.

20 Wilson, S.J. 2008. *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Serv*ices. Greenbelt Foundation and David Suzuki Foundation.

21 Kennedy, M., and Wilson, J. 2009. *Natural Credit: Estimating the Value of Natural Capital in the Credit River Watershed*. The Pembina Institute and Credit Valley Conservation.

PURPOSE OF THE REPORT

This report was commissioned by the Pacific Parklands Foundation in order to determine the non-market benefits provided by the natural capital within British Columbia's Lower Mainland (located on the west coast of Canada), including the area west to Squamish and east to Hope. This report has used existing spatial land cover databases from several sources to create a land cover database that illustrates the types of ecosystems and land use in the study area.

This report has used existing spatial land cover databases from several sources to create a land cover database that illustrates the types of ecosystems and land use in the study area

B.C.'s Lower Mainland

GEOGRAPHIC CONTEXT FOR THE REGION

One of the primary tasks for this project was to geographically define a boundary for the area commonly referred to as the Lower Mainland. The geographic boundary for the study area was difficult to develop without an official geographic definition for the Lower Mainland. However, we were able to use a portion of the Lower Mainland eco-region to develop the study boundary (Map 1).

In order to include the area east to Hope and west to Squamish, the study area was stretched along the Fraser Valley to Hope and up the coast to Squamish as the primary study area. In addition, a secondary study area for the upper watersheds was included to establish watershed-related services and values (Map 2).

The following criteria were used to define the two nested study area boundaries:

- PRIMARY STUDY AREA – The Lower Mainland Eco-region was selected as a general boundary guideline,[22] that was extended up the coast from West Vancouver to Squamish.[23]
- SECONDARY STUDY AREA – Selected based on watershed units adjacent to the Fraser Lowland Eco-section, the secondary study area includes the Fraser Canyon, Harrison River, Chilliwack, Lower Fraser and Squamish Watersheds.[24]

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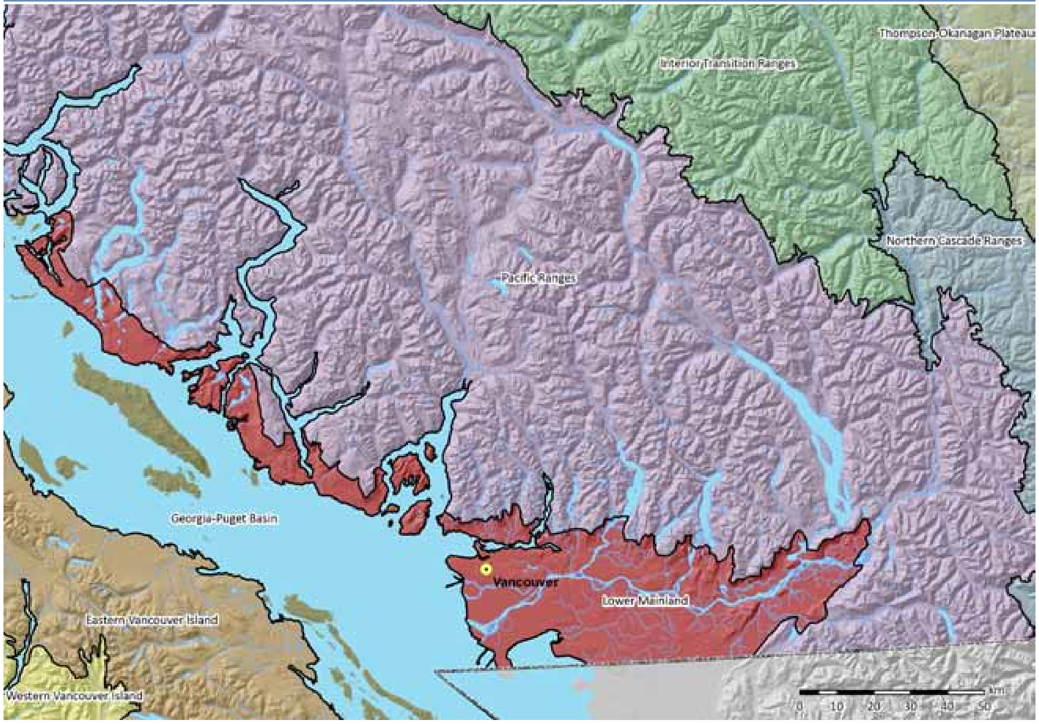
22 Demarchi, D.A. 1996. *An Introduction to the Ecoregions of British Columbia*. Wildlife Branch. Ministry of Environment, Lands and Parks. Victoria, B.C.

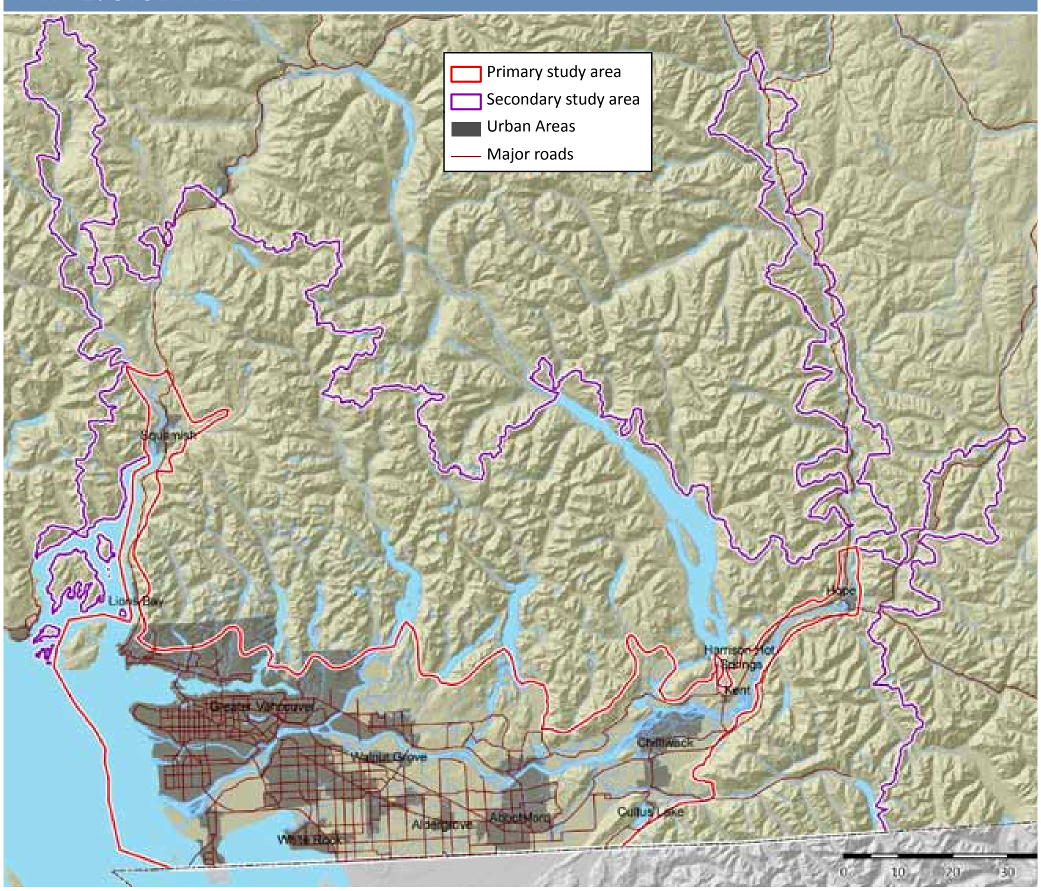
23 This Sea to Sky corridor boundary roughly follows the 780 metre elevation contour, similar to the approximate elevation of the northern boundary of the Lower Mainland Ecoregion. Valleys that extend off towards the east from the corridor were simply bridged at the point where the 780m contour turned to the east, in order to maintain a consistent north-south boundary. This elevation line was then generalized and smoothed to match the character of the rest of the Ecosection and soils based boundaries.

24 It was defined by the the B.C. watershed atlas (1:50,000 watershed units).polygons that intersected the Primary Study Area. Then, additional watersheds were added including: one within the larger Fraser Canyon Watershed, nine within the larger Harrison River Watershed, 28 within the larger Lower Fraser Watershed, and 47 within the larger Squamish Watershed. These additional watersheds were included to eliminate the interior watershed gaps resulting from step one and served to include the watersheds surrounding Howe Sound.

MAP 1: ECO-REGIONS IN THE LOWER MAINLAND



MAP 2: STUDY AREA

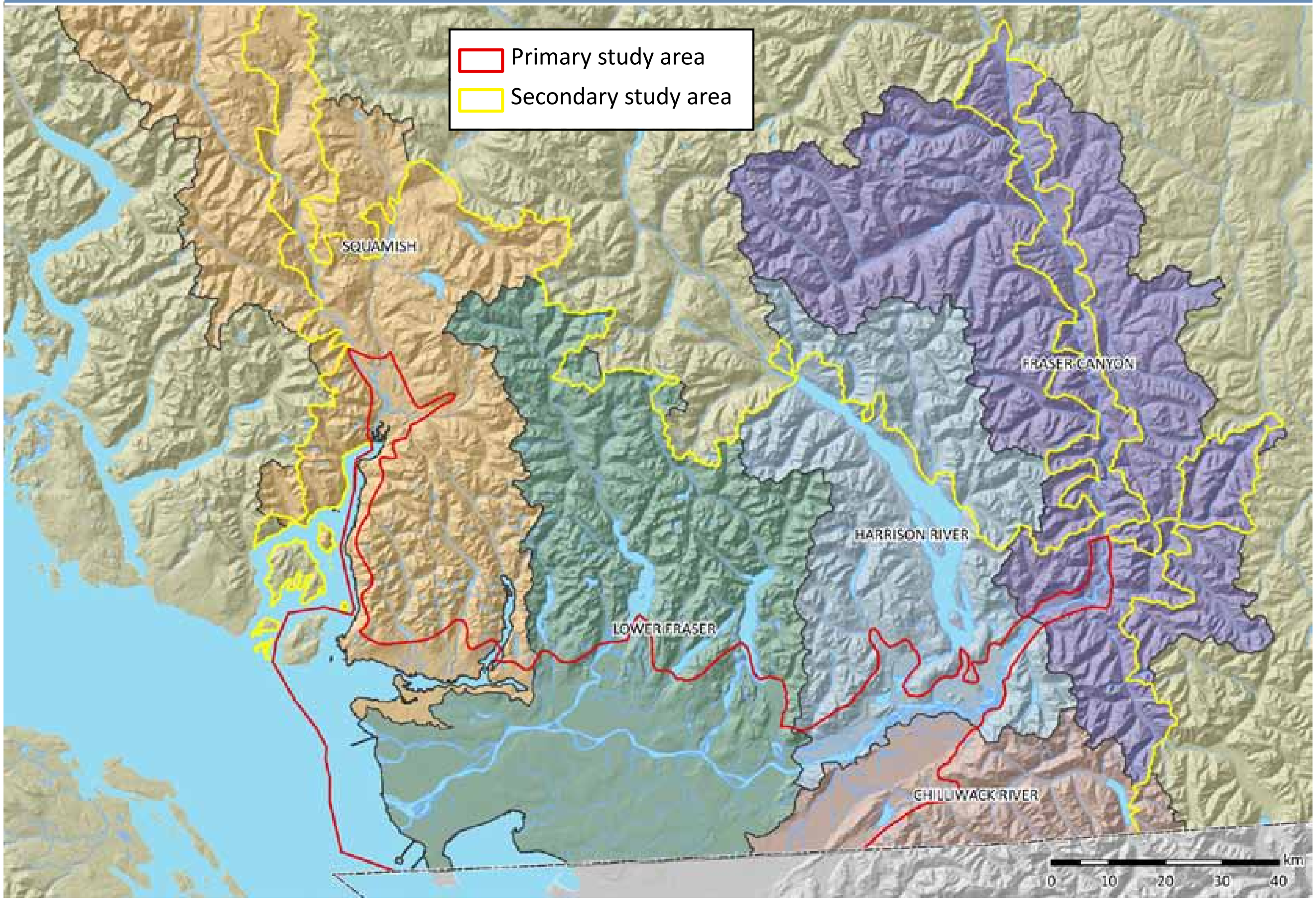


The primary study area stretches from the Lower Mainland along the Fraser Valley to Hope and up the coast to Squamish. A secondary study area for the upper watersheds was included to establish watershed-related services and values.

Two nested study areas were selected in order to develop: 1) a more constrained area that many British Columbians would commonly associate with the "Lower Mainland" – the Primary Study Area; and 2) a larger, more ecologically relevant study area selected on the basis of medium-sized watershed units – the Secondary Study Area.

The study area falls within five major watershed units known as the Fraser Canyon, Harrison River, Chilliwack, Lower Fraser and Squamish Watersheds (Map 3). The source of water for Metro Vancouver – the largest jurisdiction in the region – is rainwater and snow-melt stored in the Capilano, Seymour and Coquitlam reservoirs, which are part of the greater Squamish watershed. These two community watersheds supply up to 70 per cent of the Lower Mainland's drinking water.

MAP 3: WATERSHEDS WITHIN THE STUDY AREA



THREATS TO THE REGION'S NATURAL CAPITAL

The Lower Fraser Valley, which is part of the Primary Study Area, contains some of Canada's best agricultural lands, as well as sensitive wetland areas, forests and other natural areas.[25] Historically, much of the Lower Fraser valley was forested. Floodwaters would have brought nutrient-rich silt to the valley floor and replenished wetlands each year. By 1990, most of the forests and wetlands in the lowlands had been replaced by agricultural land use, diking systems, and urban land use.[26] The forests that remain are primarily comprised of Douglas fir and western hemlock,[27] The valley is home to two jurisdictions: The Greater Vancouver Regional District (GVRD) – now called Metro Vancouver – and the Fraser Valley Regional District (FVRD).

The major threats to natural capital in the study area include the construction of low-density suburban housing and the loss of forests, wetlands and riparian habitat to urbanization, dikes and large-scale industrial agriculture.[28] Other threats include air and water pollution, such as runoff from urban centres, agricultural lands and sewage treatment plants that increases the amount of nutrients, sediments and toxic compounds in surface and groundwater. However, there are also pressures on the existing agricultural land base. It is important to protect the current agricultural lands for food production, and to encourage practices that will protect and enhance the other natural capital in the region. In the 1970s, the Agricultural Land Reserve was created to protect land for agricultural production, which has protected much of the Fraser Valley from urban development but some lands are still being lost to other land uses.[29]

There is growing concern regarding the loss of wetlands in British Columbia. According to the B.C. government, 50 to 70 per cent of the original wetlands in the Fraser River Lowlands have already been lost, due to conversion for other land use.[30] Efforts to conserve biodiversity, greenspace and ecological agriculture in B.C.'s Lower Mainland have the potential to provide many economic benefits for communities.

The source of water for Metro Vancouver – the largest jurisdiction in the region – is rainwater and snow-melt stored in the Capilano, Seymour and Coquitlam reservoirs, which are part of the greater Squamish watershed. These two community watersheds supply up to 70 per cent of the Lower Mainland's drinking water.

HARRISON RIVER WATERSHED
PHOTO COURTESY NANCY DOWD

25 Olewiler, N. 2004. *The Value of Natural Capital in Settled Areas of Canada*. Ducks Unlimited and Nature Conservancy of Canada.

26 Fraser Basin Council. www.fraserbasin.bc.ca/regions/fvr.html

27 Boyle, C.A., and Lavkulich, L. 1997. "Carbon Pool Dynamics in the Lower Fraser Basin from 1827 to 1990." *Environmental Management*. 21: 443-455.

28 Olewiler 2004, *supra* note 25.

29 Fraser Basin Council. www.fraserbasin.bc.ca/regions/fvr.html

30 *Wetlands in B.C.* Environmental Stewardship Division, B.C. Ministry of Environment. www.env.gov.bc.ca/wld/wetlands.html

PART 3

Land Cover in the Lower Mainland

DEVELOPMENT OF LAND COVER DATABASES

Our analysis indicates forests are the dominant land-cover/ecosystem type, covering 32 per cent of the primary study area. Urbanized or developed land use is the second largest at 27 per cent.

Land cover is the observed biophysical cover on the earth's surface. A thematic land-cover map is commonly produced through classification of earth observation data (e.g. Landsat satellite imagery) using remote sensing image processing techniques. Examples of thematic classes include: water, exposed lands, built-up or urban lands, shrubland, wetland, grasslands, forested lands, agricultural lands including annual cropland, perennial crops and pasture.

To develop land cover and land use for the entire study area, several sources of geographically referenced data were obtained and reviewed.[31] The following three datasets were compiled for the study area's land cover and land use data (see Appendix A for details):

- Circa 2000 Land Cover Mapping for Agricultural regions (AAFC);
- Fraser Valley Wetlands (Canadian Wildlife Service, 2010 update); and,
- Metro Vancouver's Land Use 2006 (urban/industrial classes only).

The main land cover dataset adopted was the Circa 2000 Land Cover for Agricultural regions, available from Agriculture and Agri-Food Canada. More detailed wetland land cover data was integrated from the CWS Fraser Valley Wetlands database with an update from Metro Vancouver. In addition, Metro Vancouver 2006 land use data was used in order to provide greater detail on developed land cover classes.

31 These included EOSD (Earth Observation for Sustainable Development) data, British Columbia Vegetation Resources data, Circa 2000 Land cover Mapping for Agricultural Regions, Metro Vancouver's land use 2006 data, and Canadian Wildlife Services' Fraser River wetlands data set.

OVERVIEW OF LAND COVER DATA FOR STUDY AREA

The land use and ecosystem types within the primary study area were identified and classified based on the aggregation of databases cited above. Land cover classes are reported by area and per cent cover for the primary, secondary and total study area in Table 1.

Our land cover analysis indicates forests are the dominant land-cover/ecosystem type covering 32 per cent of the primary study area. Urbanized or developed land use is the second largest land cover at 27 per cent in the primary study area (includes residential, commercial, developed, and industrial development types), and wetlands provide significant land cover at 6 per cent. Forests, wetlands, shrublands, and grassland combined provide a cumulative natural cover of close to half the primary study area's land cover (41 per cent), and agricultural land use covers 14 per cent of the land area. In the secondary study area forests cover 74 per cent, exposed lands or alpine areas cover 14 per cent, shrublands cover 9 per cent and water covers 5 per cent of the area. The distribution of ecosystem types and land use types are summarized for the study area in Table 2.

TABLE 1: LAND COVER IN THE STUDY AREA

Land cover class	Primary study area (hectares)	Per cent of primary area	Secondary study area (hectares)	Per cent of secondary area	Total study area (hectares)	Per cent of total area
Residential	50,900	11.7%	378	0.04%	51,278	3.8%
Commercial	4,274	1.0%	0	0%	4,275	0.3%
Industrial	7,156	1.6%	0	0%	7,156	0.5%
Industrial-extraction	540	0.1%	0	0%	540	0.0%
Institutional	5,201	1.2%	2	0.00%	5,202	0.4%
Transportation/ commercial /utilities	8,176	1.9%	77	0.01%	8,253	0.6%
Fens	2,448	0.6%	0	0%	2,448	0.2%
Bogs	1,933	0.4%	0	0%	1,934	0.1%
Marshes	2,960	0.7%	172	0.02%	3,132	0.2%
Swamps	1,722	0.4%	0	0%	1,722	0.1%
Shallow water wetlands	11,809	2.7%	116	0.01%	11,924	0.9%
Gravel bars	3,477	0.8%	8	0.00%	3,485	0.3%
Unknown wetlands	1,470	0.3%	921	0.1%	2,391	0.2%
Other wetland	1,668	0.4%	3,513	0.4%	5,181	0.4%
Water	75,573	17.4%	45,572	4.9%	121,145	8.9%
Exposed land	3,178	0.7%	127,926	13.8%	131,104	9.6%
Developed	41,963	9.6%	1,971	0.2%	43,935	3.2%
Shrubland	8,339	1.9%	53,048	5.7%	61,387	4.5%
Grassland	45	0.0%	5,105	0.6%	5,150	0.4%
Annual cropland	30,318	7.0%	201	0.02%	30,519	2.2%
Perennial crops/pasture	31,656	7.3%	191	0.02%	31,847	2.3%
Coniferous	104,469	24.0%	617,964	66.8%	722,433	53.1%
Deciduous	35,369	8.1%	64,283	6.9%	99,651	7.3%
Mixed forest	293	0.1%	3,494	0.4%	3,787	0.3%
Total area	434,937	100.0%	924,942	100.00%	1,359,878	100.0%

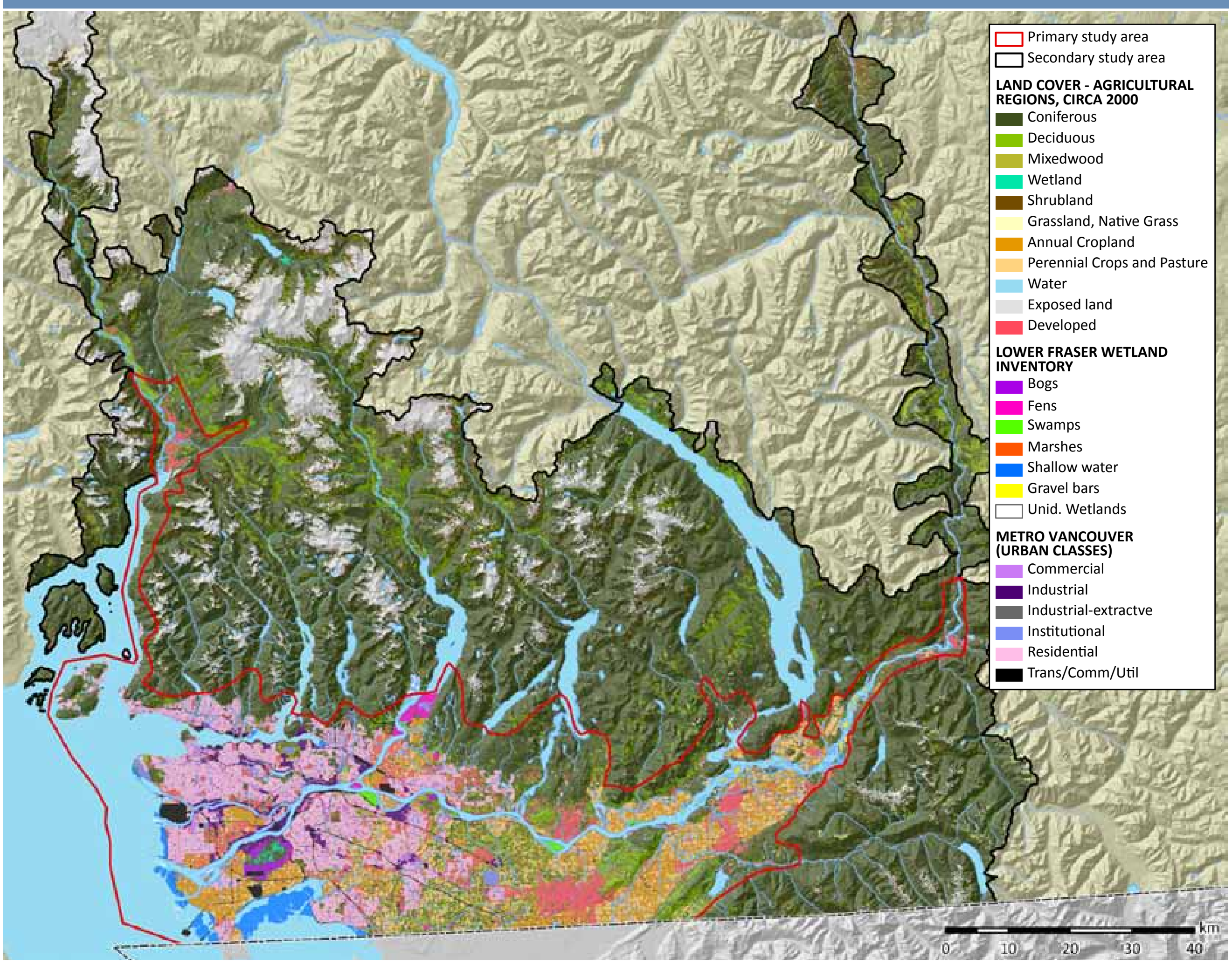
Forests and wetlands cover an estimated 65 per cent of the area, and all natural cover types provide 83 per cent of the land cover, when the primary and secondary study area are combined. The map showing the study area's land cover is illustrated in Map 4.

TABLE 2: DISTRIBUTION OF LAND COVER/LAND USE

Ecosystem type/land use	Primary study area	Secondary study area	Primary and secondary study area
		(per cent of area)	
Forests	32%	74%	61%
Developed/urban	27%	0.3%	9%
Wetlands	6%	0.5%	2%
Shrubland	2%	9%	5%
Water	17%	5%	9%
Agriculture	14%	0.04%	5%
Grassland	0.01%	0.6%	0.4%
Exposed land/alpine	0.7%	14%	10%

Note: Area may not total 100 per cent due to rounding.

MAP 4: STUDY AREA LAND COVER/LAND USE



PART 4

Study Approach

NATURAL CAPITAL VALUATION FRAMEWORK

THE DEVELOPMENT OF CONCEPTUAL frameworks and methodologies for ecosystem valuation has been improving the ability to value natural capital. The United Nations' 2005 MA reported on the condition of the world's ecosystems and their ability to provide services today and in the future.[32] The MA framework focuses on the linkages between ecosystem services and human well-being, and categorized ecosystem services into four categories:

- Supporting services: nutrient cycling, soil formation, and primary production;
- Provisioning services: food, fresh water, wood and fiber, fuel;
- Regulating services: climate regulation, flood regulation, disease regulation, and water purification; and
- Cultural services: aesthetic, spiritual, educational and recreational services.

The MA's conceptual framework, including its typology of ecosystem services, provided a springboard for several subsequent initiatives and programs. However, some peer-reviewed literature criticized the MA framework citing the inclusion of supporting services, such as nutrient cycling and soil formation, as contributing to the same end uses or "ecosystem benefits." Therefore, some ecological economists are calling for the valuation of ecosystem benefits (e.g., recreation) rather than ecosystem services to avoid "double-counting" of values for an ecosystem

The Economics of Ecosystems and Biodiversity (TEEB) – an international initiative led by the United Nations, the European Commission, and the German and UK government – is developing a state-of-the-art foundation to link economics and ecology.[33] The 2010 TEEB framework modifies the MA approach in order to avoid "double-counting." TEEB emphasizes the difference between ecological phenomena (functions), their contribution to human well-being (i.e., services) and the welfare gains

In 2005, the United Nations Millennium Ecosystem Assessment concluded that approximately 60 per cent of the world's ecosystem services are being degraded or used unsustainably, including fresh water, air and water purification, and the regulation of regional and local climate.

PHOTO COURTESY CHRIS SHORT

32 Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press. Washington, DC.

33 www.teebweb.org/Home/tabid/924/Default.aspx (accessed June 2010)

they generate (i.e., benefits).[34] As a result, TEEB is advancing a modified typology of ecosystem services. TEEB's typology for ecosystem services excludes supporting services that were included in the MA typology, and adds habitat services as an additional category to reflect the importance of habitat for migratory species and for maintaining genetic pools (Table 1).

TABLE 3: REVISED TYPOLOGY FOR ECOSYSTEM SERVICES

Developed by The Economics of Ecosystems and Biodiversity (TEEB) Initiative, 2009

Provisioning services	Regulating services	Habitat services	Cultural services
Food	Air quality regulation; climate regulation; moderation of extreme events	Maintenance of life cycles of migratory species	Aesthetic information
Water	Regulation of water flows	Maintenance of genetic diversity	Opportunities for recreation and tourism
Raw materials	Waste treatment		Inspiration for culture, art, and design
Genetic resources	Erosion prevention		Spiritual experience
Medicinal resources	Maintenance of soil fertility		Information for cognitive development
Ornamental resources	Pollination		
	Biological control		

Source: Adapted from *The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations*. September 2009 draft

Ecosystem services (ES) are the benefits derived from ecosystems. These benefits are dependent on ecosystem functions, which are the processes (physical, chemical and biological) or attributes that maintain ecosystems and the people and wildlife that live within them.

IDENTIFICATION OF ECOSYSTEM SERVICES

Ecosystem services (ES) are the benefits derived from ecosystems. These benefits are dependent on ecosystem functions, which are the processes (physical, chemical and biological) or attributes that maintain ecosystems and the people and wildlife that live within them. ES can include products received from ecosystems (e.g. food, fibre, clean air and water), benefits derived from processes (e.g. nutrient cycling, water purification, climate regulation) and non-material benefits (e.g. recreation and aesthetic benefits).[35] ES are often referred to as ecosystem or ecological goods and services (EGS), however, this study is focused on non-market ecosystem services, so the term ecosystem services (ES), will be used throughout the report.

Ecosystem processes or functions characterize ecosystems. Using the ecosystem classifications by ecosystem function developed from a number of published sources, the potential ecosystem services by ecosystem type or land cover/land use can be identified. A list of ecosystem services and each corresponding ecosystem function, processes or components are provided in Appendix C.

34 Pascual, U., and Muradian, R,. 2010. "The Economics of Valuing Ecosystem Services and Biodiversity." (Chpt. 5) in: *The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundation*. www.teebweb.org/EcologicalandEconomicFoundation/tabid/1018/Default.aspx (accessed Aug. 2010)

35 Millennium Ecosystem Assessment. 2003. *Ecosystems and Human Well-Being: A Framework for Assessment*. World Resources Institute, Island Press. Washington, D.C.

The TEEB typology for ecosystem services was categorized by ecosystem type for the study area. The potential ecosystem services provided by each ecosystem type and their benefits were identified (Appendix C). These services and benefits were streamlined for the study area based on a review of literature for ecological, social and economic features of the region (Table 4).

TABLE 4: SERVICES AND POTENTIAL BENEFITS/VALUES BY ECOSYSTEM TYPE

Ecosystem	Ecosystem services (Typology of ES from TEEB)	Potential benefits for human well-being
Wetlands	Storage of fresh water Regulation of water flows Waste treatment Carbon storage Cultural services	Food provision Climate regulation Flood control Waste processing Water supply Amenity/tourism/recreation Cultural/heritage conservation
Lakes and rivers	Waste treatment Maintenance of life cycles of migratory species Maintenance of genetic diversity Cultural services	Food provision Water supply Drainage and natural irrigation Transportation Erosion prevention Biological and genetic diversity Amenity/tourism/recreation Cultural/heritage conservation
Forests	Habitat services Pollination Air quality regulation Carbon storage Water filtration Erosion prevention Soil fertility Biological control Cultural services	Good air quality Water supply Climate regulation Pest control Biological and genetic diversity, Amenity/tourism/recreation Cultural/heritage conservation
Grassland and shrubland	Habitat services Pollination Air quality regulation Carbon storage Regulation of water flows Erosion prevention Soil fertility	Climate regulation Flood control Erosion control Air quality Biological and genetic diversity Amenity/tourism/recreation Cultural/heritage conservation
Well-managed cultivated areas	Pollination Carbon storage Erosion prevention Soil fertility	Provision of food Pollination of crops Amenity and recreation Cultural/heritage conservation

Based on the potential benefits and the economic values that were available for the study area, a final set of benefits was identified for valuation (Table 5). This study focuses on terrestrial-based values and does not include freshwater, near-shore or marine values. Services such as water regulation and water supply were attributed to land-based ecosystem types, so lakes and rivers were not evaluated to avoid double counting of the end use benefits. In addition, provisioning services were not included because they tend to be market goods.

TABLE 5: BENEFITS BY LAND COVER TYPE FOR STUDY VALUATION

Benefits	Land cover type
Climate regulation	Forests
	Wetlands
	Grasslands
	Shrublands
	Croplands
Clean air	Forests
Coastal protection	Marshes
Flood protection/ water regulation	Forests
Waste treatment	Wetlands
Water supply	Forests and wetlands
Pollination	Forests, shrublands and grassland (primary study area only)
Salmon habitat	Integral forests (greater than 100 years old)
Recreation/tourism	Forests and wetlands
	Farm-based
Local food production	Croplands
Total	All

Measuring the value of goods or services is fairly straightforward when they have a market-determined value. However, determining the non-market values for ecosystem services is much more difficult because they do not have an established price.

NON-MARKET ECOSYSTEM VALUATION

Measuring the value of goods or services is fairly straightforward when they have a market-determined value. However, determining the non-market values for ecosystem services is much more difficult because they do not have an established price. Measuring their values is difficult because of a lack of ecological and economic information.

There are several techniques that have been developed to determine economic values for non-market ecosystem services. These include: 1) direct market valuation approaches such as market-based, cost-based, and production function-based valuations; 2) revealed preference approaches such as travel cost and hedonic pricing methods; and, 3) stated preference approaches such as contingent valuation, choice modeling, and group valuation methods.[36] Direct market valuation methods use data from actual markets and thus reflect preferences or costs to individuals. Revealed preference techniques are based on the observation of individual choices that are related to the ecosystem service under study. Stated preference methods simulate a market and demand for ecosystem services using surveys that provide hypothetical scenarios of changes in the supply

36 Pascual and Muradian 2010, *supra* note 34.

of ecosystem services. These surveys assess the willingness to pay or accept compensation by surveys.

The TEEB framework recommends that values be derived from direct market valuation approaches where possible. In the absence of this information, price information can be derived from market information indirectly associated with the service. If both direct and indirect price information are not available then hypothetical scenarios created by stated preference methods may be used to determine the value.[37]

Cost-based valuation approaches have been used in this report as the first priority for valuation methods. Avoided damage cost assesses the value for ecosystem services based on what society would have to pay if ecosystems and their services are diminished and/or damaged. In other words, the value is the avoided costs that would be incurred in the absence of those services. Replacement cost is related to avoided cost but focuses on ecosystem services that could be replaced using another natural source or human-made systems. Cost-based or production-function methods were used for valuation to determine the values in this report except for the valuation for recreation and local food production which were based on revealed and stated preference methods, respectively. The valuation approaches used to evaluate each ecosystem service benefit is provided in Table 6.

TABLE 6: VALUATION METHOD USED BY BENEFIT TYPE

Benefits	Valuation method
Climate regulation	Avoided damages cost based on the value of the avoided costs of carbon emitted to the atmosphere. Forest age class was used to determine carbon storage for forests.
Clean air	Pollution removal rate for trees was based on research by USDA Forest Service based on average air pollution removal capacity for Seattle, Washington. Valuation is based on avoided costs.
Coastal protection	No valuation was undertaken
Flood protection/ water regulation	Replacement value costs for runoff control
Waste treatment	Replacement cost based on waste treatment plants in Metro Vancouver region. Based on original analysis of the wetland capacity to absorb excess nitrogen and phosphorus.
Water supply	Replacement costs of 10 per cent of current condition of the study area's forest cover in watersheds.
Pollination	Production function value: value and proportion of crops that depend on pollination in Lower Mainland.
Salmon habitat	Production function value: value of integral watershed/ forest cover for Coho salmon fishery
Recreation/tourism	Value of nature-based recreation and consumer surplus
	Travel cost (farm-based recreation)
Local food production	Travel cost

37 Ibid.

PART 5

Value of Natural Capital in the Lower Mainland

Forest ecosystems are tremendous reservoirs of carbon (C). Over half of the global land-based carbon (terrestrial organic soil and biomass C) is currently stored in forests.

PHOTO COURTESY NANCY OLIVER

USING THE LAND-COVER CLASSES AREA DATA for each ecosystem/land cover type, ecosystem services have been ascribed to each land-cover/ecosystem type, and the potential benefits are being identified using the conceptual framework described above. It should be noted that these services and values represented in this report are a first step in setting a baseline inventory for the region's ecosystem services. The next steps would be further analysis in terms of: 1) the impacts of environmental degradation would provide a more accurate assessment of the current value; and, 2) modeling of the values for ecosystem services based on potential changes in land use to determine the incremental changes in values for decision-making. However, these next steps were beyond the scope and available data for the current study.

CLIMATE REGULATION

Forest ecosystems are tremendous reservoirs of carbon (C). Over half of the global land-based carbon (terrestrial organic soil and biomass C) is currently stored in forests. Forests store enormous amounts of carbon in standing trees and in the soil because of their cumulative years of growth.[38] Forest carbon storage refers to the total amount of carbon contained in an ecosystem at a given time. Carbon sequestration refers to the annual amount of carbon uptake by an ecosystem after subtracting the carbon released to the atmosphere due to respiration, disturbance and decomposition.

BC's forests store a significant amount of carbon – with coastal forest storing up to 1,300 tonnes of carbon per hectare. Forests cover approximately 60 million hectares of the province. 54 per cent of BC's forests are within the Montane Cordillera ecozone, with smaller forest area in the Pacific Maritime, Boreal Cordillera, Taiga Plains and Boreal Plains ecozones.[39] The Lower Mainland is within the Pacific Maritime zone, one of the highest regions in Canada for forest ecosystem carbon storage (Kurz and Apps 1999). The 1999 Carbon Budget compiled by Kurz and Apps estimated average

38 Pregitzer, K.S., and Euskirchen, E.S. (2004). "Carbon cycling and storage in world forests: biome patterns related to forest age." *Global Change Biology*. 10:2052-2077.

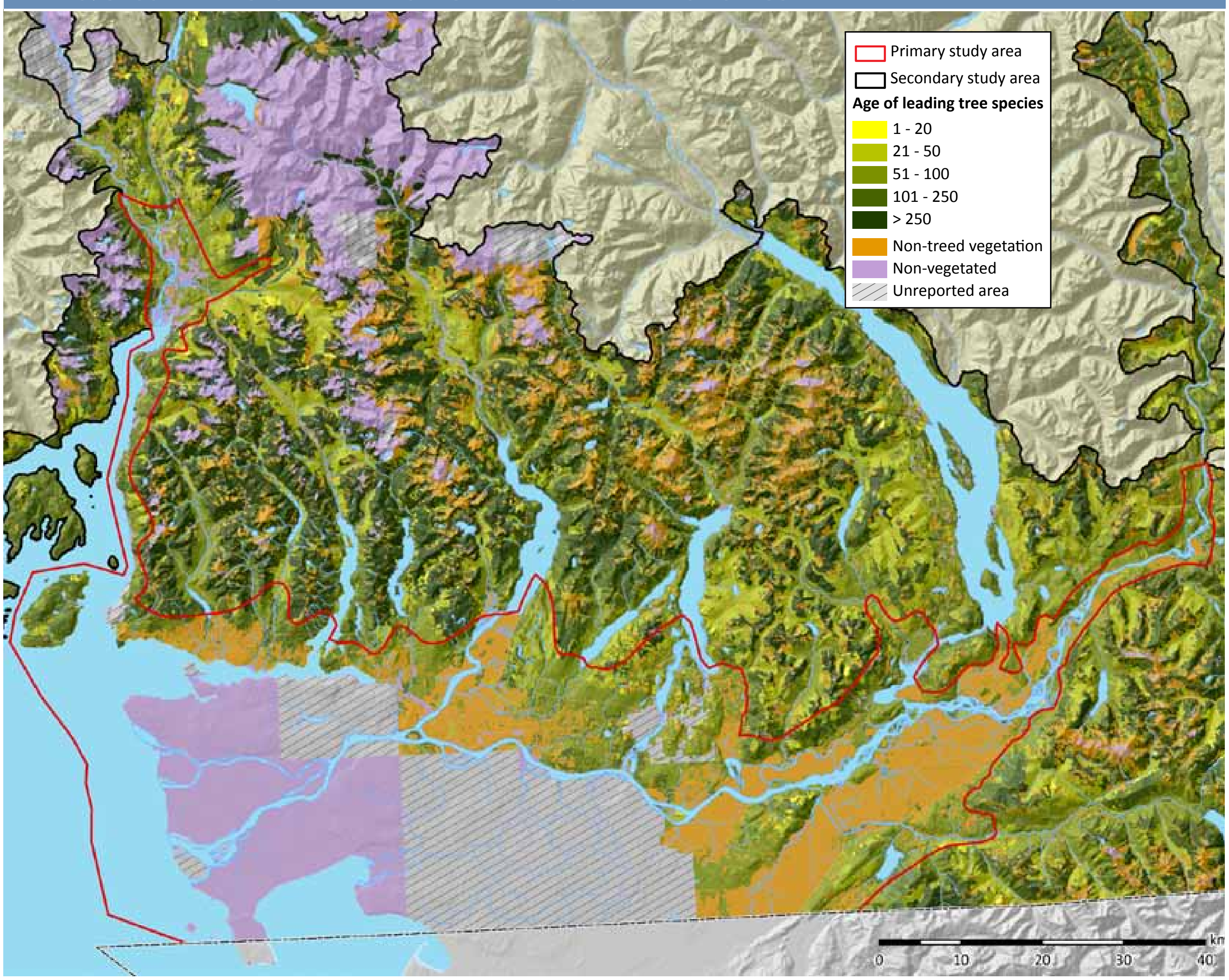
39 2001 National Forestry Inventory (CANFI 2001; http://nfi.cfs.nrcan.gc.ca/canfi/data/index_e.html)

carbon content for biomass and soils for this region to be 374.6 tonnes of carbon per hectare, based on a simulation model.[40]

However, two more recent studies have reviewed the site data study results in the North American Pacific Northwest region (similar to the ecosystems in our study area) The first study found that mature cool temperate forests in the region contain an average of 642 tonnes of carbon per hectare.[41] The second study reports a mean total ecosystem carbon content of 487 tonnes per hectare in the Pacific Maritime ecozone. Both studies were based on site studies and provide more recent data for the region. As a result, in this study we have taken an average of the two values (564.5 tC/ha) to estimate carbon storage.

Forest carbon storage refers to the total amount of carbon contained in all the components of a forest ecosystem at a given time. First, we estimated forest carbon storage based on carbon content estimates using our average of 564.5 tonnes per hectare and the forest land-cover data for the study area. Thus, assuming that all forest lands are mature forests and equal, the total carbon that could

MAP 5: SECONDARY STUDY AREA FOREST LAND COVER BY AGE CLASS



Source: BC Vegetation Resources Inventory

40 Kurz, and Apps 1999. A 70-Year Retrospective of Carbon Fluxes in the Canadian Forest Sector. *Ecological Applications*. 9:526-547.

41 Keith, H., Mackey, B.G., and Lindenmayer, D. 2009. *Re-evaluation of Forest Biomass Carbon Stocks and Lessons from the World's Most Carbon Dense Forests*. PNAS. 106: 11635-11640.

be stored by the study area's forest ecosystems is 466.2 million tonnes in the total study area.

To assess the carbon storage more accurately, forest land cover by age was obtained from the B.C. Vegetation Resources Inventory database (Map 5 on page 31).

Old forest (greater than 250 years old) was estimated to have 564.5 tonnes of carbon per hectare (100 per cent of the average carbon content estimate), and younger forests were estimated to have 55 tC/ha (1 to 20 years), 169 tC/ha (21 to 50 years), 423 tC/ha (51 to 100), 508 tC/ha (101 to 250). Because a different spatial database was accessed to assess the forest age distribution, the per cent cover for each forest age class for the primary and secondary study areas was used to estimate the proportion of the forest cover in each age class for our land cover data. Based on these estimates the total carbon stored was estimated at 362.3 million tonnes of carbon.

The economic value of the carbon stored by ecosystems can be estimated based on the avoided costs (i.e. damages avoided), replacement cost or the market price of carbon trading.

The economic value of the carbon stored by ecosystems can be estimated based on the avoided costs (i.e. damages avoided), replacement cost or the market price of carbon trading. The amount of carbon stored can be valued based on the value of the avoided costs of carbon emitted to the atmosphere. The IPCC (Intergovernmental Panel on Climate Change) reports that the average social cost of carbon based on the impacts of climate change is $52 (2005 C$) per tonne of carbon (i.e. environmental, economic and social costs).[42] Based on this value, forest land cover provides an average annual value per hectare estimated at $1,709 in the primary study area and $1,858 in the secondary study area. The total value is $1.5 billion per year (Table 7). The avoided cost is used here because it reflects the actual damages avoided in terms of the predicted impacts of climate change due to rising concentrations of carbon dioxide in the atmosphere if the carbon stored were to be released.

We can compare the estimated amount and value of carbon stored based on forest age land cover with the original estimate where on average all of the forest land-cover stored 564.5 tonnes of carbon. The value of the carbon that could potentially be stored is 466.2 million tonnes in the total study area, which would be worth $1.9 billion each year annualized over 20 years (2005 C$).

The difference illustrates the cost of the current state of the forest land-cover based on forest age. The difference in carbon storage over the whole study area is an estimated 104 million tonnes worth annually $434 million over 20 years ($525 per hectare per year).

TABLE 7: AMOUNT AND VALUE OF FOREST CARBON STORED BY FOREST LAND COVER (2005 C$)

Forest age	Land cover area in primary study area (ha)	Total forest carbon stored (tonnes C)	Land cover area in secondary study area (ha)	Total forest carbon stored (tonnes C)	Value of carbon stored per hectare ($/ha over 20 yrs @5%)	Total annualized value million c$ (2005)
1 to 20 yrs	1,331	75,139	6,746	75,139	$472	1.91
21 to 50 yrs	18,035	3,054,232	113,187	3,054,232	$1,415	92.86
51 to 100 yrs	86,609	36,668,387	153,173	36,668,387	$3,538	424.19
101 to 250 yrs	30,064	15,274,096	216,103	15,274,096	$4,246	522.58
> 250 yrs	3,902	2,203,011	196,068	2,203,011	$4,717	471.68
unknown	187	53,018	465	53,018	$2,359	0.77
Forest total	140,130	75,139	685,741	57,327,883		1,513.98

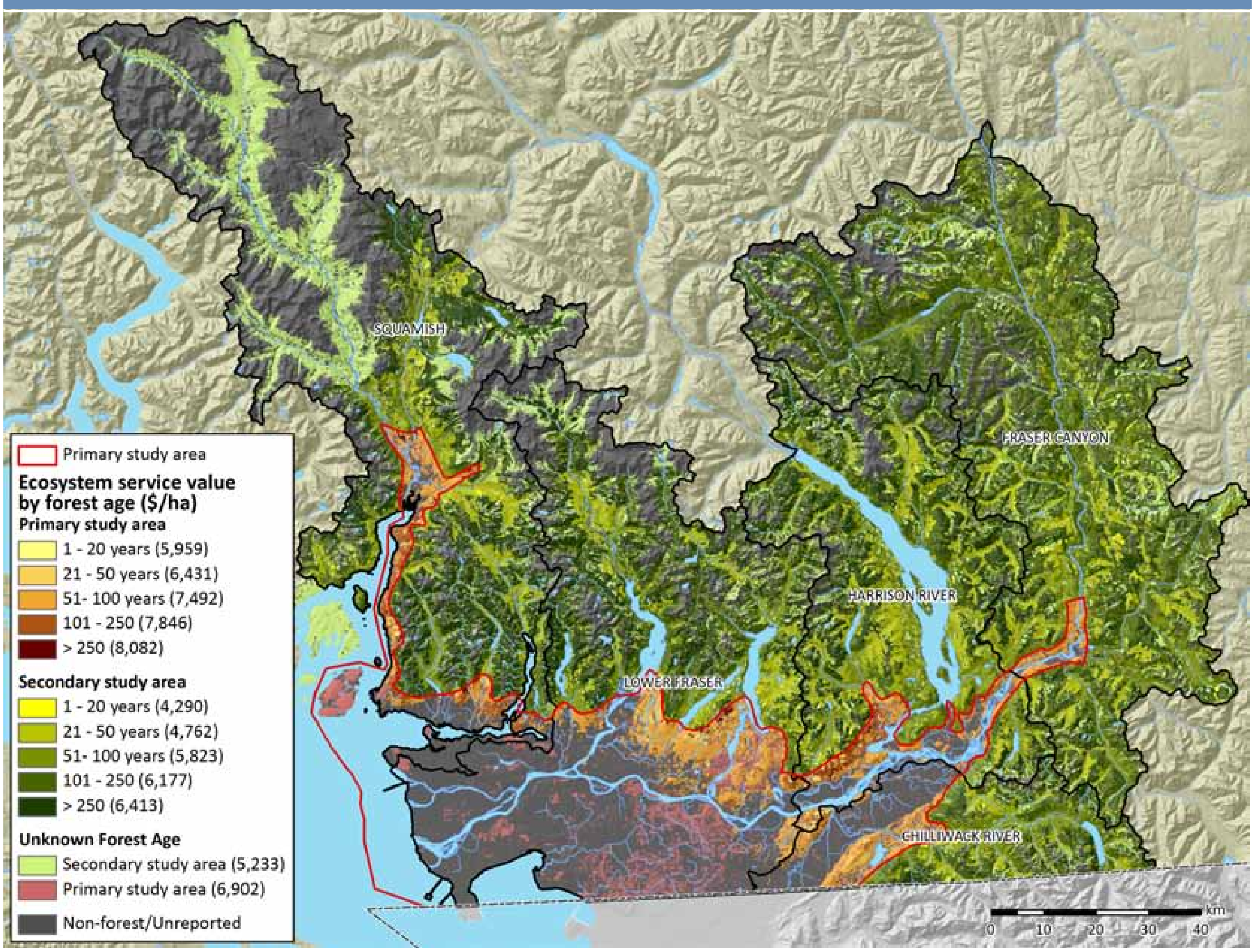
42 IPCC. (2007): *Summary for Policymakers.* In: *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press, Cambridge, UK, 7-22.

Maintaining the integrity of natural ecosystems is important for conservation and for climate change mitigation and adaptation purposes. As the climate continues to change, the conservation of natural ecosystems will become even more vital because of their immense stores of carbon, and for their provision of species habitat and migration corridors. When a forest is converted to a field or a housing development, the disturbance of natural vegetation and soil results in the release of carbon dioxide to the atmosphere. Consequently, protecting the carbon stores that exist in our natural ecosystems will minimize the loss of ecosystem carbon.

ANNUAL CARBON UPTAKE (SEQUESTRATION) BY FORESTS

The annual uptake of carbon (i.e., net carbon sequestration) was calculated using CITYgreen software.[43] CITYgreen's carbon module quantifies the removal of carbon dioxide by trees based on the estimated age distribution by assigning three age distribution types. Type 1 represents a distribution of young trees, type 2 represents older trees, and type 3 describes a site with a balanced distribution of ages. Each type is associated with a multiplier (i.e., tonnes of carbon taken up per hectare), which is combined with the overall area of the site's canopy to estimate how much carbon is removed (additional details are included in the Appendix).

MAP 6: ECOSYSTEM SERVICE VALUE BY FOREST AGE



43 American Forests. CITYgreen software ArcGIS 8.x www.americanforests.org/productsandpubs/citygreen/

TABLE 8: VALUE OF CARBON STORED BY WETLANDS

Wetland type	Area (ha)	Tonnes of carbon per hectare	Total carbon stored (tonnes)	Value per hectare ($/ha)	Annual value per hectare (over 20 yrs@5%)	Total value millions$	Annual total value millions$
Swamp	1,722	355	611,186	$18,483	$1,483	$31.8	$2.6
Marsh	3,132	252	789,862	$13,131	$1,054	$41.1	$3.3
Shallow water	11,924	169	2,011,713	$8,785	$705	$104.8	$8.4
Fen	2,448	351	858,273	$18,256	$1,465	$44.7	$3.6
Bog	1,934	642	1,242,110	$33,448	$2,684	$64.7	$5.2
Other wetland	11,057	269	2,976,307	$14,017	$1,125	$155.0	$12.4
Total	32,217		8,489,450			$287.1	$23.0

The study area's wetlands store 3.8 million tonnes of carbon in their soils and peat.

The total tree canopy cover area annually takes up (i.e., sequesters) an estimated 620,014 tonnes of carbon in the total study area (105,221 tonnes of carbon in the primary study area) or an annual average of 0.8 tonnes of carbon per hectare. This service is worth an estimated value of $32.2 million in the total study area and watersheds ($5.5 million per year in the primary study area), or about $39 per hectare based on the average avoided cost of carbon emissions (C$52/tC).

CARBON STORED BY WETLANDS

The carbon stored in wetland soils carbon was determined using Canada's Soil Organic Carbon Database.[44] The soil organic carbon data was extracted spatially from this geo-referenced database by land-cover type. According to this database, the study area's wetlands store 3.8 million tonnes of carbon in their soils and peat. The annual value of the carbon stored is an estimated $23 million based on the average damage cost of carbon emissions ($52 per tonne of carbon), over 20 years (Table 8). The annual value per hectare ranges from $705 to $2,684 per hectare depending on the type of wetland (i.e. open water, bog, marsh, swamp and fen).[45]

ANNUAL CARBON UPTAKE BY NON-TIDAL WETLAND ECOSYSTEMS

The annual carbon sequestered is calculated based on the global average of sequestration rates for non-tidal wetlands, which range from 0.2 to 0.3 tonnes of carbon per hectare. Using the average rate of sequestration (0.25 tonnes per hectare per year),[46] the annual rate of carbon uptake (8,054 tonnes) is worth an estimated $13 per hectare ($0.3 million per year).

ANNUAL CARBON UPTAKE BY TIDAL WETLAND ECOSYSTEMS

Most global carbon studies have focused on land-based ecosystems for carbon storage estimates,

44 Tarnocai, C., and B. Lacelle. 1996. *Soil Organic Carbon Database of Canada*. Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Canada.

45 Total value is converted to an annual value as a 20 year annuity at 5%, adapted from Anielski and Wilson 2007.

46 Carbon balance of peatlands. www.aswm.org/science/carbon/quebec/sym43.html

and have not accounted for small carbon-storing ecosystems such as tidal saline wetlands. However, studies have recently been undertaken in the salt marshes of the world. Globally combined, salt marshes and mangroves store at least 44.6 million tonnes of carbon per year, and this is reportedly an underestimate because detailed data is not available for some regions. The overall carbon sequestration rate on an annual basis is 210 grams of carbon dioxide per square metre per year.[47] This is an order of magnitude greater than carbon sequestration by peatlands, which sequester carbon at a rate of 20 to 30 grams of carbon dioxide per square metre per year.

There are approximately 10,077 hectares of tidal wetlands in our study area. Using the global average sequestration rate, these wetlands absorb 21,161 tonnes of carbon per year, worth an estimated $1.1 million based on the average avoided costs of carbon emissions. The total carbon sequestered each year by non-tidal and tidal wetlands is therefore worth an estimated $1.39 million.

CARBON STORED BY GRASSLANDS AND SHRUBLANDS AS CARBON BANKS

Grassland ecosystem services are often overlooked, yet they provide several vital services such as climate regulation, genetic biodiversity, and soil conservation. Grasslands cover 5,150 hectares in the study area – less than one per cent of the total area.

Grasslands store more carbon than cultivated lands because they provide a complete vegetative cover and plants grow for seven to eight months of the year, instead of the typical three to five months for agricultural crops.[48] When grasslands are ploughed or converted to agricultural lands carbon is released to the atmosphere. Even when grassland is restored, carbon recovery is slow.[49]

The carbon stored in the study area's grassland soils was quantified based on the average soil organic carbon for grassland cover using the Soil Organic Carbon Database of Canada.[50] The average soil carbon content for grassland cover in the study area was therefore assessed as 142 tonnes of carbon per hectare. Based on this estimate, the grasslands within the study area store about 732,780 tonnes of carbon, worth an annual value of $3 million ($594 per hectare) annualized as an annuity over 20 years.[51] The value of carbon is based on the avoided cost of damages due to increasing carbon emissions estimated by the IPCC (see the forest carbon section).

Shrublands cover 61,386 hectares of the study area. Soil carbon storage was also estimated by extracting soil carbon data by land cover type from the Soil Organic Carbon Database of Canada.[52] Based on this assessment, the estimated carbon stored in shrubland soils is 240 tonnes of carbon per hectare, worth about $1000 per hectare per year. The total carbon stored is an estimated 14.7 million tonnes worth $61 million per year, annualized as an annuity over 20 years. The value of carbon is based on the avoided cost of damages due to increasing carbon emissions estimated by the IPCC (see the forest carbon section).

Grassland ecosystem services are often overlooked, yet they provide several vital services such as climate regulation, genetic biodiversity, and soil conservation.

47 Chmura, G.L., Anisfeld, S.C., Cahoon, D.R., and Lynch, J.C. (2003). "Global carbon sequestration in tidal, saline wetland soils." *Global Biogeochemical Cycles*.

48 Sala, O.E., and Paruelo, J.M. 1997. "Ecosystems Services in Grasslands." In: *Nature's Services: Societal Dependence on Natural Ecosystems*. G.C. Daily (Ed.). Island Press. Washington, D.C.

49 Ibid.

50 Data from the Soil Organic Carbon Database of Canada was extracted by land cover type for determining grassland soil carbon. Tarnocai, C., and B. Lacelle. 1996. *Soil Organic Carbon Database of Canada*. Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Canada.

51 Carbon value is calculated using the average damage cost of carbon emissions reported by the Intergovernmental Panel on Climate Change ($52/tC). The total value of $5,460 per hectare is converted to an annual value using a 20-year annuity investment formula.

52 Tarnocai, C., and B. Lacelle. 1996. *Soil Organic Carbon Database of Canada*. Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Canada.

CARBON STORED BY CROPLANDS

The amount of carbon stored in the soils of croplands was determined using Canada's Soil Organic Carbon (SOC) Database.[53] Data was extracted spatially from this geo-referenced database by land-cover type. The average carbon stored by cropland soils is an estimated 316 tonnes per hectare. The annual value is $41 million, or $660 per hectare, based on the avoided cost of carbon emissions. However, this value does not reflect the impact of agricultural land use because the SOC database reflects general values for the region based on soil types.

On average, Canada's croplands restored soil organic carbon between 1996 and 2001. In 2001, the mean rate of soil organic carbon change was 29 kilograms per hectare per year.[54] Annual carbon sequestration by land in permanent cover sequesters more carbon than tilled land.[55] Although the rate of sequestration depends on the type of cover, the change from conventional crop tillage to permanent cover has been estimated to increase sequestered carbon by 1.8 tonnes of carbon dioxide (0.5 tC) per hectare per year compared with conventional crop cover.[56] In BC, 38 per cent of croplands showed an increase in soil organic carbon; negligible to small changes occurred on 34 per cent; and 28 per cent of lands had decreasing levels. This is a result of a decrease in tillage and soil erosion risk in B.C.'s croplands in general. Between 1981 and 2001, there was a reduction in cereal crops that require intensive tillage, and an increase in alfalfa and hay crops that require very little tillage. 21 per cent of seeded areas are under conservation tillage and 14 per cent direct seeded with no-till.[57] More recent data and regional data were not readily available. As a result, we were not able to provide analysis of the current impact on the state of the SOC stored by croplands.

CLEAN AIR

Trees intercept airborne particles by retaining them on their leaves and studies show that trees can remove eight to 12 grams of air pollutants per square metre of canopy.

Trees are essential for good air quality because they produce oxygen for our air.[58] Forests and trees also provide improvements in air quality by removing air pollution through absorption using their leaves. They also intercept airborne particles by retaining them on their leaves. Studies show that trees can remove eight to 12 grams of air pollutants per square metre of canopy.[59]

CITYgreen software was used to assess the amount of air pollutants removed by the tree canopy cover across the study area. CITYgreen calculates the value of air cleansing by trees using average removal rates of carbon monoxide, nitrogen dioxide, nitrogen dioxide, particulate matter and sulphur dioxide by trees. Our analysis results indicate that trees in the total study area remove about 100 kilograms of pollutants per hectare, and a total of 82.6 million kilograms per year (14 million

53 Ibid.

54 McConkey, B., Hutchinson, J., Smith, W., Grant, B. and R. Desjardins. 2005. Soil Organic Carbon. Pages 108 – 113, in Lefebvre, A., W. Eilers, et B. Chunn (eds.). 2005. *Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series – Report #2*. Agriculture and Agri-Food Canada, Ottawa, Ontario.

55 Sala, O.E., and Paruelo, J.M. 1997, "Ecosystems Services in Grasslands". In: *Nature's Services: Societal Dependence on Natural Ecosystems,* G.C. Daily (Ed.), Island Press, Washington, D.C.

56 Smith W.N. et al. 2001. "Estimated changes in soil carbon associated with agricultural practices in Canada." *Canadian Journal of Soil Science*. 81:221-227 (used by Olewiler 2004, *supra* note 25).

57 McConkey et al, *supra* note 54.

58 Each healthy mature tree produces about 260 pounds of oxygen every year. Two trees can provide enough oxygen for a family of four. Environment Canada. 2005. *Envirozine*. Issue 58. www.ec.gc.ca/envirozine.

59 Nowak, D.J., Wang, J., and Endreny, T. 2007. "Environmental and Economic Benefits of Preserving Forests within Urban Areas: Air and Water Quality." In: *The Economic Benefits of Land Conservation*. The Trust for Public Land. San Francisco, California. www.tpl.org/tier2_rp1.cfm?folder_id=175 (accessed Nov. 5, 2009)

TABLE 9: VALUE OF AIR POLLUTION REMOVED BY TREES (PRIMARY AREA)

Primary area	Kilograms/yr	Value	Value/kg	Kilograms per hectare	Value/ha
Carbon monoxide	840,682	$790,241	$0.94	6.0	$5.64
Ozone	4,623,753	$31,288,934	$6.77	33.0	$223.31
Nitrogen dioxide	2,101,706	$14,222,243	$6.77	15.0	$101.51
Particulate matter	4,343,525	$19,624,047	$4.52	31.0	$140.06
Sulfur dioxide	2,101,706	$3,474,120	$1.65	15.0	$24.80
Totals	14,011,372	$69,399,585	$4.95	100.0	$495.31

TABLE 10: VALUE OF AIR POLLUTION REMOVED BY TREES (TOTAL STUDY AREA)

Total study area	Kilograms/yr	Value	Value/kg	Kilograms per hectare	Value/ha
Carbon monoxide	4,953,714	$4,656,491	$0.94	6.0	$5.64
Ozone	27,245,427	$184,369,808	$6.77	33.0	$223.31
Nitrogen dioxide	12,384,285	$83,804,458	$6.77	15.0	$101.51
Particulate matter	25,594,189	$115,634,548	$4.52	31.0	$140.06
Sulfur dioxide	12,384,285	$20,471,223	$1.65	15.0	$24.79
Totals	82,561,900	$408,936,528	$4.95	100.0	$495.31

kilograms per year in the primary study area). The kilograms removed per hectare range from 6 kilograms per hectare for carbon monoxide to 33 kilograms per hectare for ozone (Table 9 and 10). The annual value of this service is $409 million per year ($69 million per year in the primary study area), or $495 per hectare.

Biological structures such as salt marshes, sea grass beds, and coral reefs attenuate waves and as a result provide coastal protection from the damages caused by flooding and storm events.

COASTAL PROTECTION

Biological structures such as salt marshes, sea grass beds, and coral reefs attenuate waves and as a result provide coastal protection from the damages caused by flooding and storm events.[60] This is becoming a critical service in many regions because of the increased risk of flooding and storm events – both in terms of frequency and severity – due to present and predicted climate change. Salt marshes play a leading role in intertidal areas, dissipating wave and tidal energy and thereby reducing the cost of flood defense measures. In addition, they absorb huge amounts of water when inundated and then slowly release it afterwards, which can also prevent flooding.

Beaumont et al. (2008) report that an earlier study undertaken by King and Lester (1995) estimated that the cost savings provided by salt marshes in terms of flood defense were UK£0.38 to UK£0.71 million (C$0.6 to C$1.1 million) per hectare in capital costs, and UK£1,700 per hectare (C$2,667.22) for annual maintenance costs.[61] Similar economic analysis has not been undertaken

60 Koch et al. 2009. "Non-linearity in ecosystem services: temporal and spatial variability in coastal protection." *Frontiers in Ecology and the Environment*. 7:29-37.

61 Beaumont, N.J., Austen, M.C., Mangi, S.C., and Townsend, M. (2007) "Economic valuation for the conservation of marine biodiversity." *Marine Pollution Bulletin*. doi:10.1016/j.marpolbul.2007.11.013. (Beaumont et al. values were adjusted to 2005 prices; conversions to Cdn dollars are using current values).

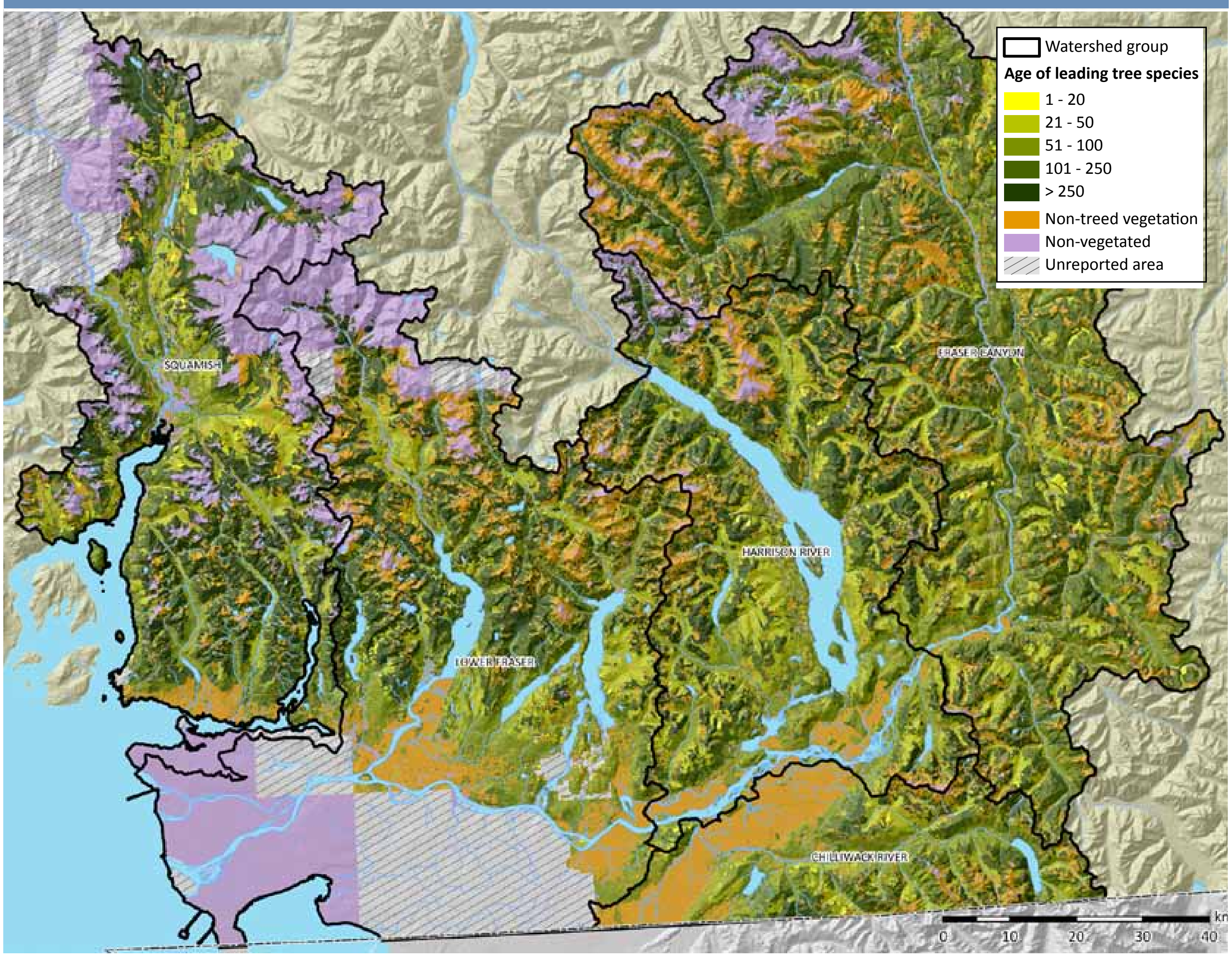
for coastal protection by marshes in the Lower Mainland area. As a result, no value has been included in this study. However, it is recommended that further research examine the values for the region's vast coastal areas.

FLOOD PREVENTION/ WATER REGULATION

Forest land cover regulates the flow of water providing protection against flooding and soil loss/ erosion. The loss of forest cover, therefore, affects stream flows leading to instability in drainage systems, reduced infiltration of water into soils, and increased peak flows. In other words, changes in stream flow due to forest loss results in: 1) lower water levels in dry seasons, 2) higher than normal water levels in wet seasons or storms, 3) greater amounts of sediment entering rivers, and 4) increased water temperatures.[62]

Field research demonstrates that forests/tree cover significantly improve the quality of water. Studies by the Environmental Protection Agency in the United States show that forests in rural

MAP 7: FOREST AGE COVER IN THE PRIMARY AND SECONDARY STUDY AREA



62 Ribaudo, M.O. 1986. "Regional estimates of off-site damages from soil erosion." In: *The off-site costs of soil erosion*. (Ed.) T.E. Waddell. (Proceedings of a symposium held May 1985.)

areas improve water quality because trees divert rainwater into the soil where bacteria and micro-organisms filter out pollutants.[63] This filtering significantly reduces the sediment, pollutants and organic matter that reach streams. Riparian forests (i.e., forested buffers along waterways) are especially effective at reducing non-point source pollution, such as nitrogen and nitrates in runoff and trapping sediment.

Our study area falls within five major watershed units known as the Fraser Canyon, Harrison River, Chilliwack, Lower Fraser and Squamish Watersheds. Map 7 illustrates the forest age cover across the study area and watersheds. This area was analyzed to determine the value of water filtration provided by forests in the area's watersheds.

The economic value of water regulation by forests is calculated as a replacement value using the CITYGreen software. Analysis of the study area's total forest cover was assessed in terms of the replacement construction costs for water runoff control if the current forest cover was removed and converted for urban land use. In other words, the forest cover provides savings because it provides green infrastructure for the region. The total annual savings are an estimated $1.2 billion or $1,502 per hectare – $295 million or $615 per hectare in the primary area, and $1.15 million or $1,684 per hectare in the secondary study area.[64] These values represent the total value for all forest cover over 20 years in each respective area. However, if we were to use this analysis to assess the costs for a loss in a portion, the values could be used to assess land use decisions. For example, if 10 per cent of the primary study area's tree canopy cover was converted to urban land use, the replacement cost in terms of water regulation (i.e., stormwater management) would be an estimated $8.6 million.

WASTE TREATMENT

Wetlands can absorb nutrients such as nitrogen (N) and phosphorus (P) that runs off farmlands in excessive amounts because of fertilizer, manure use, and from livestock. The amount that a wetland can absorb varies depending on the type, size, plants and soils. Estimates range from 80 to 770 kilograms per hectare per year for phosphorus removal, and 350 to 32,000 kilograms per hectare per year for nitrogen removal.[65] We applied the low-end removal rates to the wetland cover in the study area to estimate the wetland area's capacity. Our results show that the wetlands have the capacity to remove 2.6 million kilograms of phosphorus and 11.3 million kilograms of nitrogen each year.[66]

Agriculture and Agri-Food Canada (AAFC) report agricultural environmental indicators (AEI) for census years 1981 to 2001. The residual soil nitrogen on farmlands and the risk of water contamination by nitrogen from farmlands are two indicators in this series of reports. Residual soil nitrogen (RSN) is the amount of nitrogen (N) that has been applied to soils but not removed by the harvested portion of crops. In other words it is the difference between all nitrogen inputs, such as fertilizer, manure and natural processes, and the nitrogen removed both by the crops harvested and natural

Our results show that the wetlands have the capacity to remove 2.2 million kilograms of phosphorus and 9.6 million kilograms of nitrogen each year.

63 Winogradoff, D.A. 2002. *Bioretention Manual*. Prince Georges County, MD. Department of Environmental Resources Programs and Planning Division. www.goprincegeorgescounty.com/Government/AgencyIndex/DER/ESD/Bioretention/pdf/intro_bioretention.pdf (cited by Nowak, *supra* note 59.)

64 Based on construction cost of $57 per cubic metre. Total cost savings are $3.4 billion. However, annualized savings are reported here, calculated over 20 years at 6% interest by CityGreen software. See appendix 1 for more details on the methodology of the calculations.

65 Reported by: Olewiler 2004, *supra* note 25.

66 27,488 hectares of wetlands multiplied by the low-end estimates of removal rates of 80.3 kg/ha/year of phosphorus and 350 kg/ha/yr of nitrogen.

processes (volatilization and denitrification).[67] In 2001, the majority of farmland in British Columbia was in the very low to moderate RSN categories (0 to 30 kg N/ha).

The second AEI indicator measures the risk of water contamination by nitrogen (IROWC-N). The risk of contamination to water is determined by the ability of the natural ecosystems to regulate, filter and absorb the nutrients in the runoff. Across Canada, the average nitrate loss from agricultural lands increased by 25 per cent from 6 kilograms per hectare in 1981 to 7.6 kilograms per hectare in 2001, and nitrate concentration in water was 24 per cent higher in 2001 than 1981.[68] In BC, the majority of farmland was in the very low to moderate risk classes (0 to 19.9 kg of N/ha).

Across Canada, the average nitrate loss from agricultural lands increased by 25 per cent from 6 kilograms per hectare in 1981 to 7.6 kilograms per hectare in 2001, and nitrate concentration in water was 24 per cent higher in 2001 than 1981.

Based on the average residual soil nitrogen and the risk of water contamination by nitrogen indicators, the estimated nitrogen loss from the primary study area's agricultural lands is 311,830 to 623,660 kilograms per year, based on an annual loss of 5 to 10 kilograms N/ha (i.e., average risk class reported for the majority of B.C.'s farmlands).

The costs of removing nitrogen (N) and phosphorus (P) by waste treatment plants have been estimated to range from $3 to $8.50 per kilogram of nitrogen and $22 to $61 per kilogram of phosphorus based on water treatment costs in Metro Vancouver.[69] The respective average replacement costs can be used as a proxy for the value of wetland waste treatment services for excess nitrogen. The amount of excess nitrogen per total wetland area ranges from about 10 to 19 kilograms per hectare of wetlands, a value ranging from $29.42 per hectare to $164.54 (an average value of $96.98).

The capacity for phosphorus removal by wetlands was calculated using a low-end estimate from the literature (80 kg/ha/yr) multiplied by the wetland area in the primary study area. The value of wetland services for treating excess phosphorus was then calculated using the estimated amount of excess phosphorus multiplied by the average cost of phosphorus removal by waste treatment plants in Vancouver ($22 to $61/kg). The national average for excess phosphorus (14.3 kg/ha/yr) was used as an estimate for the study area. To estimate the total excess phosphorus, the average excess phosphorus runoff was multiplied by the total agricultural land (891,883 kg).

67 Drury, C.F. et al. 2005. "Nitrogen Use Efficiency." In Lefebvre, A.W. et al. 2005. *Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series – Report #2*. Agriculture and Agri-Food Canada. Ottawa, Ontario. www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1182179116194&lang=e (accessed Nov. 2007).

68 De Jong, R. et al. . 2005. "Nitrogen." In Lefebvre, A.W. et al. 2005. *Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series – Report #2*. Agriculture and Agri-Food Canada. Ottawa, Ontario. www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1182179116194&lang=e (accessed Nov. 2007).

69 Reported by Olewiler 2004, *supra* note 25.

The amount of excess phosphorus per total wetland is therefore an estimated 27.7 kilograms per hectare of wetlands, a value ranging from $604.85 per hectare to $1,694.12 (an average value of $1,149.48). The two average replacement values for excess nitrogen removal and phosphorus removal were tallied to estimate the total value for waste treatment by wetlands ($1,283/ha).

WATER SUPPLY

A safe and reliable source of water is critical for all living things, both now and in the future. Water pollution comes from point sources such as industrial discharges and wastewater treatment plants. It also is derived from non-point sources including runoff from agricultural lands and facilities, urban areas, construction sites, and failed septic tanks. In the United States, damages to streams, lakes and estuaries from non-point source pollution have been estimated to cost between $7 billion and $9 billion each year.[70]

Forested watersheds are vital for a clean and regular supply of drinking water.

Poor water quality degrades recreational areas and fish habitats, which affects human health by increasing insect and waterborne diseases. It also leads to odour problems and diminished aesthetic values. Forests and wetlands can reduce non-point source water pollution because they filter, store, and transform pollutants into non-harmful forms.

The study area's drinking water comes from rivers, streams or underground sources (i.e., aquifers). All of these sources are linked in a watershed by the ecosystems that capture, filter and deliver water. The best way to protect sources of water is through watershed planning because water flows cross traditional boundaries such as towns and cities. Forested watersheds are vital for a clean and regular supply of drinking water. Protected forests provide higher quality water with less sediment and fewer pollutants than water from watersheds with unprotected forests.[71]

The water filtration services provided by forests have been calculated as the replacement cost of the current condition of the study area's watersheds. The cost of treatment is based on a US study that found the cost of treatment for surface water supplies statistically varies depending on the per cent forest cover in the watershed source area.[72] This study concluded that there is a 20 per cent increase in water treatment costs for each 10 per cent loss in forest cover. In other words, where forest cover is lower, water treatment costs more.

The results from this study have been used to interpret the value of water filtration services by forests and wetlands in the study area's watersheds. The economic value for the benefit of water filtration was based on the potential increase in water treatment costs if the current forest/wetland cover declined from its current average cover. Thus, the value is based on the additional cost for water treatment if the current natural cover declined.

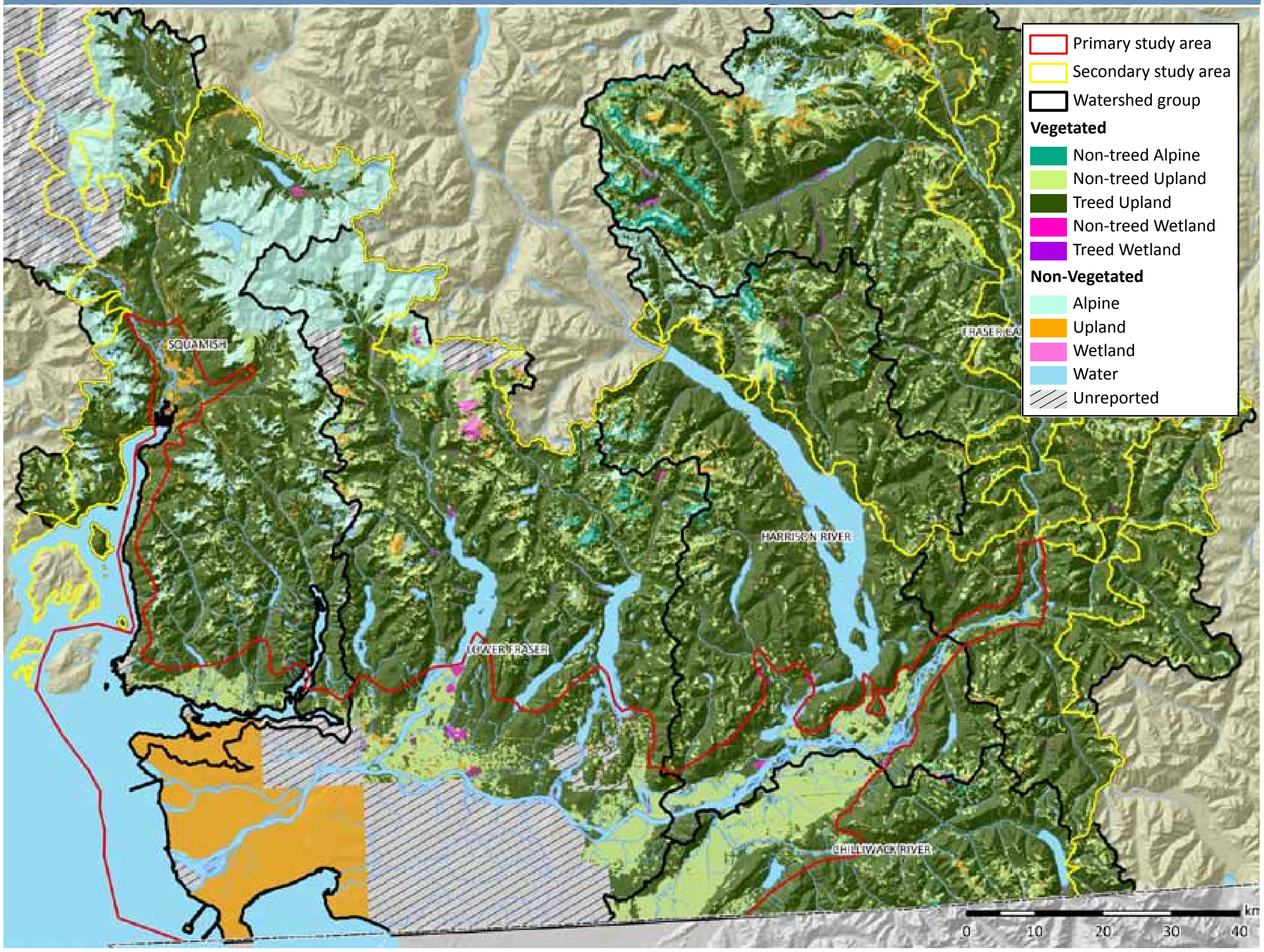
First, we assessed the proportion of forest cover in the study area's watersheds, and the per cent cover of forests and wetlands in each major watershed. Our analysis for the community watersheds found an average of 83 per cent forest/wetland cover, and analysis for the greater watersheds including Chilliwack, Harrison River, Fraser Canyon, Lower Fraser and Squamish found an average of 67 per cent forest/wetland cover. The vegetated and non-vegetated land cover within the study area is illustrated in Map 8.

70 Ribaudo, M.O. 1986. "Regional estimates of off-site damages from soil erosion." In: *The off-site costs of soil erosion*. (Ed.) T.E. Waddell. (Proceedings of a symposium held May 1985.)

71 Dudley, N. and Stolton, S. 2003. *Running Pure: The importance of forest protected areas to drinking water*. World Bank/WWF Alliance for Forest Conservation and Sustainable Use. Washington DC.

72 Ernst, C., Gullick, R. and Nixon, K. 2007. "Protecting the Source: Conserving forest to protect water." In *The Economic Benefits of Land Conservation*. The Trust for Public Land. www.tpl.org

MAP 8: VEGETATED COVER IN THE STUDY AREA'S WATERSHEDS



The current cost of water treatment was estimated as 50 per cent of the current amount paid for water by households in the Greater Vancouver Water District ($1.36*.05 per cubic metre).[73] Our analysis estimates that water treatment costs would increase from $0.68 to $0.82 per cubic metre if the average forest and wetland cover declined by 10 per cent, and to $1.18 per cubic metre if forest and wetland cover declined by 30 per cent. The economic value calculated here is the avoided cost due to an incremental loss (a conservative 10 per cent), in forest and wetland cover. In other words, it is the value of maintaining current forest and wetland cover.

If we transfer the value estimated above for water filtration services provided by forests and wetlands in the Greater Vancouver Water District watersheds ($1,889/ha/yr) to all forest and wetland cover in the primary study area, the annual value of water filtration services is an estimated $264 million. If we apply the same value per hectare to all the forest and wetland cover in the watersheds of the full study area, then the total value is $1.6 billion.

It is useful for comparison to consider the total replacement cost for water. If the daily residential water use in the GVWD had to be replaced by bottled water, the daily cost would be $1.6 billion (1,091 million litres at $1.50 per litre), or $597 billion per year.

73 Cost of water paid by households was calculated as 50 per cent of the average household daily water use (503 litres/ 0.503 m3) mulitipied by the average amount paid per day (based on the average annual household bill for GVWD ($250/yr). The statistics are from the GVRD 2008 Water Consumption Statistics.

Insect pollination is necessary for most fruits and vegetables including annual crops such as tomatoes, peppers and strawberries, as well as tree fruits such as apples and peaches.

PHOTO COURTESY STEVE PETERS

POLLINATION

Pollination can be defined as the transfer of pollen from one flower to another, which is critical for fruit and seed production in many plants. About 80 per cent of all flowering plant species are dependent on pollination, making it critical to the overall maintenance of biodiversity.[74] Insect pollination is necessary for most fruits and vegetables including annual crops such as tomatoes, peppers and strawberries, as well as tree fruits such as apples and peaches.

About 30 per cent of the world's food production comes from crops that depend on pollinators like bees, insects, bats, and birds.[75] The value of bee pollination for crops in Canada has been conservatively estimated at $1.2 billion per year.[76] In the United States, the economic value of all pollinator services for agriculture is an estimated $5.7 to $13.4 billion per year.[77]

Honeybees provide about 90 per cent of managed pollination services, however wild bees also add significant value to crops. For example, the annual contribution of wild pollination services in the United States is estimated at more than $3 billion annually;[78] in Costa Rica, wild bees increase coffee yields by 20 per cent, increasing crop values by up to $393 per hectare;[79] visits by bumblebees can increase tomato fruit set by 45 per cent and fruit weight by 200 per cent;[80] and In Canada, wild

74 Commission on Genetic Resources for Food and Agriculture. Pollinators: Neglected Biodiversity of Importance to Food and Agriculture. Food and Agriculture Organization of the United Nations (FAO). Rome (June 11-15, 2007). ftp://ftp.fao.org/ag/cgrfa/cgrfa11/r11i15e.pdf (accessed February 2008)

75 Klein,A.-M., et al. 2007. "Importance of pollinators in changing landscapes for world crops." *Proceedings of the Royal Society B*. 274:303-313.

76 Environment Canada. 2003. "Protecting Plant Pollinators." Envirozine. Issue 33 (June 26, 2003). www.ec.gc.ca/EnviroZine/english/issues/33/feature3_e.cfm (accessed February 2008)

77 Tang, J, Wice, J., Thomas, V.G., and Kevan, P. 2005. *Assessment of the Capacity of Canadian Federal and Provincial Legislation to Conserve Native and Managed Pollinators*. The International Network of Expertise for Sustainable Pollination. University of Guelph. Canada. www.pollinator.org/Resources/Laws%20Affecting%20Pollinators-Canada.pdf (accessed March 2008).

78 Losey, J.E., and Vaughan, M. 2006. "The Economic Value of Ecological Services Provided by Insects." *Bioscience*. 56:311-323.

79 Ricketts, T.H., Daily, G.C., Ehrlich, P.R., and Michener, C.D. 2004. "Economic value of tropical forest to coffee production." *Proceedings of the National Academy of Sciences*. 101:12579-12582;

80 Greenleaf, S.S., and Kremen, C. 2006. "Wild bee species increase tomato production and respond differently to surrounding land use in Northern California." *Biological Conservation*. 133:81-87

pollinators produce larger and more symmetrical apples in orchards, providing marginal returns of $250 per hectare.[81]

Many pollinators are in decline due to habitat destruction and pesticide use. Diverse habitats that provide a variety of flowers provide the best forage for pollinators. Flower-rich field borders, windbreaks such as hedgerows, forests and riparian buffers encourage a wide variety of pollinators.[82]

The B.C. Ministry of Agriculture and Lands has estimated the value of pollination in the province at $267.3 million per year. The value of pollination is calculated for crops that depend on pollinators and the proportion of dependence for each crop receipt value.[83] In order to estimate the value for the study area, the proportion of each crop reported grown in the Metro Vancouver area and the Fraser Valley was used to determine the value (percent grown in study area multiplied by the total BC crop value).[84] The total estimated benefit provided by pollination services is $247.8 million each year. Only the primary study area was included in this valuation because this area contains the majority of agricultural lands.

In this study, the value of pollination services has been attributed to the forest land and grassland because they provide habitat, forage and food for wild and managed pollinators. The proximity of natural habitat to cropland is significant for optimum yields and increased farm production. For example, a Canadian study found canola yield is correlated to the proximity of uncultivated areas,[85] and studies that examined pollination and surrounding land use for tomato and sunflower production found that natural habitat near farms increases pollination services.[86] The total annual value ($247.8 million) ascribed to natural cover area for the benefit of pollination services in the primary study area is $1,668 per hectare.[87]

Diverse habitats that provide a variety of flowers provide the best forage for pollinators. Flower-rich field borders, windbreaks such as hedgerows, forests and riparian buffers encourage a wide variety of pollinators.

FRESHWATER SALMON HABITAT

Knowler et al. (2003) estimated the value of protecting watersheds for salmon fish habitat in terms of the value that forested drainage areas contribute to maintaining freshwater spawning and rearing habitat used by coho salmon. Their study examined how changes in land use affect the productivity of coho salmon populations and the resulting economic impacts on commercial salmon fisheries in the Strait of Georgia, B.C. The values determined by their study ranged from $0.93 to $2.63 per hectare of drainage watershed, or about $1,322 to $7,010 per kilometre of salmon stream length depending on the extent of degradation in the watershed. The range of values were estimated in a

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81 Kevan, P. G. 1997. "Honeybees for better apples and much higher yields: study shows pollination services pay dividends." *Canadian Fruitgrower*. (May 1997): 14, 16. (cited by FAO)

82 Environment Canada. 2003. "Protecting Plant Pollinators." *Envirozine*. Issue 33 (June 26, 2003). www.ec.gc.ca/EnviroZine/english/issues/33/feature3_e.cfm (accessed February 2008)

83 Estimated annual value of Honeybee and Bumblebee Pollination in BC 92004). Ministry of Agriculture and Lands. Source: Statistics Canada Farm Cash Receipts (November 2005). www.agf.gov.bc.ca/apiculture/statistics/pollin.value2004.pdf

84 Percent of crop grown in Metro Vancouver and Fraser Valley are from: 2008 Metro Vancouver Agricultural Overview and 2008 Fraser Valley Regional District Agricultural Overview. (2005$). Sustainable Agriculture Management Branch. B.C. Ministry of Agriculture and Lands.

85 Greenleaf, S.S., and Kremen, C. 2006. "Wild bee species increase tomato production and respond differently to surrounding land use in Northern California." *Biological Conservation*. 133:81-87; Greenleaf, S.S., and Kremen, C. 2006. "Wild bees enhance honey bees' pollination of hybrid sunflower." *Proceedings of the National Academy of Sciences*. 103:13890-13895.

86 Ibid.

87 Natural cover area includes forest land, grassland, and shrubland cover in the primary study area. Total area is 148,514 hectares.

case study area in the South Thompson watershed, the largest tributary of the Fraser River and the Strait of Georgia in southern B.C.[88] This study found that degradation of the watershed's from pristine condition resulted in reduced economic gains equal to a net present value of $2.63 per hectare of watershed area ($3.27/hectare in 2005 dollars).

Based on this study, the value of pristine watershed was valued for maintaining salmon freshwater habitat. We assumed that forested watershed areas greater than 100 years old were integral or pristine. According to our analysis of forest age cover, 60 per cent of the forest land in the watersheds within our study area is greater than 100 years old.[89] We have therefore estimated that the value of integral watershed areas in our study area (i.e., greater than 100 years old) are worth $1.6 million in terms of their role in protecting salmon fish habitat in the watershed streams and rivers.

Knowler et al. (2003) estimated the value of protecting watersheds for salmon fish habitat in terms of the value that drainage areas contribute to maintaining habitat.

RECREATION AND TOURISM

BC is known for its spectacular coasts, inlets, islands and mountains. Tourism is the second largest income generator in the province. Three economic studies were reviewed for recreation values in the study area. First, a study by Tourism British Columbia and BC Wilderness Tourism Association reported that wilderness and nature-based tourism represented 12 per cent of total revenues by B.C.'s tourism sector in 2005. In that year, 1.2 million tourists spent approximately $1.2 billion on nature-based tourism in the province. The amount spent was expected to be $1.4 billion in 2008. As the majority of tourism operations are on the coast, they estimate that at least half of this amount ($700 million) is directly based on salmon resources and/or salmon-based nature tourism. They also report that the value added to the B.C. economy is estimated at $1.5 billion, using standard multipliers.

The second study is a 1996 national survey that estimated the economic impact of nature-based recreation by residents of the province.[90] In 1996, British Columbia's residents spent $2.3 billion (2005$) on recreational activities that were in or associated with natural areas. In order to interpret this value for the study area, we assumed that all recreational activities were associated with the province's forested lands that cover almost 50 per cent of the province's land base (47.4 million hectares). Given this assumption, the value of nature-based recreation can be estimated at $48 per hectare of forest per year.

The third study is a report on the economic value of protection of old growth forests in the Fraser Timber Supply Area of BC by Knowler et al. 2008.[91] Their values are from the Outdoor Recreation Survey from 1989/1990 because the survey was the most recent consumer surplus study for the area. Consumer surplus reflects the amount consumers value outdoor recreation beyond how much they spend on outdoor recreation. According to this report, 52 per cent of the recreational user days occur in the Vancouver Forest Region worth an estimated $79.19 per hectare per year.

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88 Knowler, D.J., MacGregor, B.W., Bradford, M.J., and Peterman, R.M. 2003. "Valuing freshwater salmon habitat on the west coast of Canada." *Journal of Environmental Management*. 69:261-273.

89 Forest land cover age groups were extracted from the B.C. Vegetation Resources Inventory for the study area. (see appendix)

90 Duwors, E. et al. 1999. *The Importance of Nature to Canadians: The Economic Significance of Nature-Related Activities*. Environmental Economics Branch. Environment Canada. Ottawa, Canada.

91 Knowler, D., and Dust, K. 2008. *The Economics of Protecting Old Growth Forest: An Analysis of Spotted Owl Habitat in the Fraser Timber Supply Area of British Columbia*. School of Resource and Environmental Management. Simon Fraser University.

In order to estimate a total economic value for nature-based recreation, our study includes the economic value of nature for recreation by BC's residents as $48 per hectare per year, and the economic value beyond what is spent as $79.19. Therefore, the total annual value is estimated as $127 per hectare for forest and wetland land cover. The tourism study was not included because the figures were not broken down for the study area region.

The second approach for valuation asked survey respondents how much more they would be willing to pay for the Abbotsford-grown corn instead of California-grown corn.

FARM-BASED RECREATION

The value of farm-based recreation in the Fraser Valley has been determined by a 2007 study in Abbotsford, B.C. Abbotsford residents indicated that they visited farms for recreation three times a year on average. Based on travel costs incurred to make these trips, the annual benefit was estimated at $171/acre ($422/hectare).[92] As a conservative estimate, we have estimated that 50 per cent of the study area's agricultural lands have the same recreational value. Based on this assumption the annual value for farm-based recreation is an estimated $13.1 million.

LOCAL FOOD PRODUCTION

The value of local food production was estimated in the Fraser Valley by the same 2007 study referenced for farm-based recreation. The value of local food production was assessed by travel cost method and market price differential method. The travel cost method was based on a postal survey that indicated local residents buy from local farms on average 12 times a year and each round trip averages 9.4 kilometres.

The second approach for valuation asked survey respondents how much more they would be willing to pay for the Abbotsford-grown corn instead of California-grown corn. The average response was $0.91 per dozen cobs of corn (a 46 per cent premium over corn from California).[93] In addition, the results from a survey for the price differential between Abbotsford and Vancouver markets for locally produced food found that Vancouver shoppers were paying approximately 35 per cent more than Abbotsford shoppers for the same local products (i.e., strawberries, raspberries, corn, and blueberries).

We have estimated that about 25 per cent of Metro Vancouver households make 6 trips a year (half the number in the survey) spending $20 per trip. The estimated travel costs are estimated then to be $24 million, or $382.48 per hectare per year (total value divided by total agricultural lands in study area).[94] This is a conservative estimate because a similar study undertaken for Metro Vancouver found that 95 per cent of households in MV are willing to pay $73 per year to preserve farmland, and that over 90 per cent of households rated local food production as one of the top three benefits of having farmland in the region.[95]

92 *Public Amenity Benefits and Ecological Services Provided by Farmland to Local Communities in the Fraser Valley: A Case Study in Abbotsford, B.C.* 2007. Strengthening Farming Report. File Number 800.100-1. B.C. Ministry of Agriculture and Lands.

93 Ibid.

94 Total number of households in Metro Vancouver is 795,130. From: Robbins, M., Olewiler, N., and Robinson, M. 2009. *An Estimate of the Public Amenity Benefits and Ecological Goods Provided by Farmland in Metro Vancouver*. B.C. Ministry of Agriculture and Lands.

95 Ibid.

PART 3

Case Studies

FRASER LOWLANDS WETLANDS CASE STUDY

Metro Vancouver spatial data department has recently completed an update for the CWS Fraser Lowlands wetland inventory data. The update includes analysis of changes in wetland land cover in the Lower Mainland between 1989 and 2009.Their results report that in 1989 the total wetland area within the Fraser Lowlands inventory study area was 29,432 hectares (Table 11).

Between 1989 and 2009, an average of 67 hectares of wetland was lost per year. The total wetlands lost and the type of land cover conversion is provided in Map 9. Between 1989 and 1999, 1,046 hectares of wetland land cover was lost with the greatest proportion converted to agricultural

TABLE 11: WETLAND LOSS AND LAND COVER TYPE CONVERSION, 1999/2009

Land cover type conversion	Total loss (ha)		Total loss (%)		Wetlands affected*	
Loss type	1989–1999	1999–2009	1989–1999	1999–2009	1989–1999	1999–2009
Agriculture	469.9	109.1	0.45	0.35	26	44
Golf course	244.2	1.0	0.23	0.00	4	1
Landfill	150.2	0.0	0.14	0.00	1	0
Residential	50.5	31.4	0.05	0.10	12	13
In transition	49.0	149.1	0.05	0.47	12	19
Storage and transport	46.1	0.0	0.04	0.00	10	0
Manufacturing	18.6	4.1	0.02	0.01	12	9
Commercial	8.6	4.3	0.01	0.01	6	4
Transportation	8.5	13.2	0.01	0.04	15	10
No apparent loss	0.7	0.0	0.00	0.00	2	0
Recreation	0.1	2.3	0.00	0.01	1	1
Total	1,046	314			101	101

land (45 per cent) and golf courses (23 per cent). In the 2009 update, wetland loss was estimated at a lower rate. Between 1999 and 2009, 314 hectares of wetland cover was lost with the greatest proportion converted to agricultural land (35 per cent) and transition lands (47 per cent).

The majority of wetland conversion for agriculture purposes between 1989 and 1999 was for cranberry production, whereas wetland conversion for agriculture between 1999 and 2009 was primarily for growing forage or grain crops. In both the 1999 and 2009 wetland loss updates, Metro Vancouver wetland loss was greater than the Fraser Valley Regional District. The 1999 update reported that Metro Vancouver converted/lost 987 hectares of wetlands (59 hectares in FVRD) and, in 2009, a reported 191 hectares were converted/lost in Metro Vancouver regional district (115 hectares in FVRD).

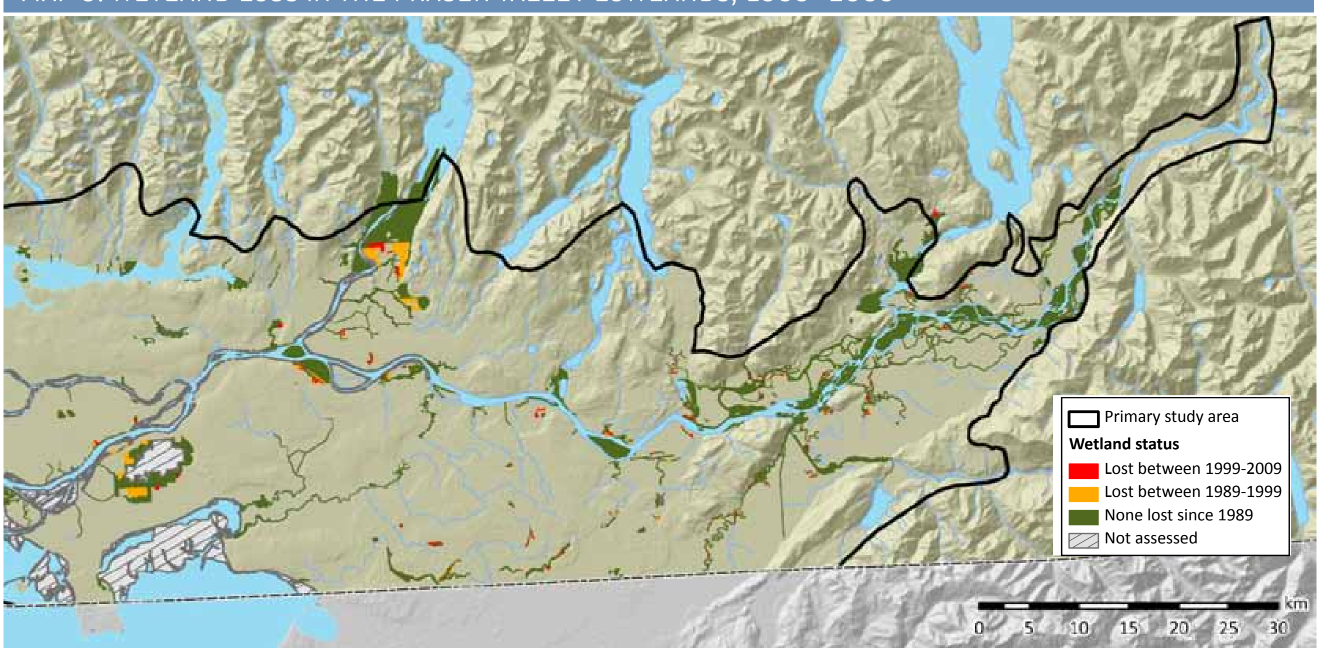
The majority of wetland conversion for agriculture purposes between 1989 and 1999 was for cranberry production, whereas wetland conversion for agriculture between 1999 and 2009 was primarily for growing forage or grain crops.

The average value estimated for wetlands is $9,008 per hectare. Using this estimate, we can quantify an estimate of the cost of losing these wetlands. Five hundred and seventy-nine hectares were converted to agricultural lands, which provide an estimated $1,855 per hectare, a loss of $7,153 per hectare (total of $4.1 million). The other 781 hectares of wetland were converted to developed land use types, therefore the loss in ecosystem services was $9,008 per hectare (total of $7 million per year in lost services). The overall total in lost ecosystem services is estimated to cost a total of $11.1 million per year.

ECOSYSTEM SERVICES PROVIDED BY ORGANIC AGRICULTURAL PRACTICES

Modern agriculture has increased the amount of food that can be grown on each hectare of farmland, but higher productivity has come at a cost. Agricultural productivity is based on the use of ecosystem services, as well as inputs such as modified seeds, pesticides and fertilizers. Conventional farming that uses a high level of inputs can suppress the ability of farmland to provide ecosystem services such as natural pest control and pollination. Public health and water quality can also be affected.

MAP 9: WETLAND LOSS IN THE FRASER VALLEY LOWLANDS, 1989–2009



For example, pesticide use in the United States has been estimated to cost $10 billion each year due to losses in public health, pesticide resistance in pests, crop losses, bird losses, and groundwater contamination.[96]

Studies indicate that the supply of ecosystem services differs depending on the type of agricultural practices.[97] A New Zealand study directly measured the comparative ecosystem services provided by organic and conventional farmland. They found that organic farming provides better ecosystem services that are worth 4 to 9 times more per hectare per year.[98] Even when the market values for food and raw materials are included, the total economic value of organic farmland is greater than conventional land.

The difference in value is due to greater services such as biological control of pests, plant residue breakdown by soil micro-organisms, ground water recharge and shelterbelt permeability. Each hectare of organic farmland provided services worth more than $1,000 in additional economic value ($1,091/hectare/year). Although the field measurements of the ecosystem services are specific to the area studied, the comparative values can be applied to our study area to demonstrate the potential benefits of improved agricultural practices.

The proportion of organic farms is approximately 2 per cent of farms across the Fraser Basin.[99] Using this statistic, it is estimated that 1,247 hectares of cropland are organic in the study area. The values for the ecosystem services provided by agricultural lands from the New Zealand study were not transferred for this study because of the differences between the regions. However, for the purpose of this case study, the potential benefits that could result from an increase in organic farming in our study area are evaluated.

If the proportion of organic farms in the Fraser Valley and Metro Vancouver increased to 10 per cent, the economic benefits provided by ecosystem services could increase by over $1 million per year. These values are not used in our assessment; however, they provide a useful illustration of the potential benefits that could result from increasing ecological practices such as promoting the conversion from conventional farming to organic farming.

There is an incredibly large potential market for organic food. Organic food sales in North America have grown at an average rate of 20 per cent per year over the past 10 years.[100] Canadians, alone, spend about $1.3 billion on organic food.[101] Not only would an increase in organic farming benefit the provision of ecosystem services, such a move would also reduce damage costs associated with conventional farming practices.

Even when the market values for food and raw materials are included, the total economic value of organic farmland is greater than conventional land.

96 Pimental, D. 2005. "Environmental and Economic Costs of the Application of Pesticides in the United States." *Environment, Development and Sustainability*. 7:229-252.

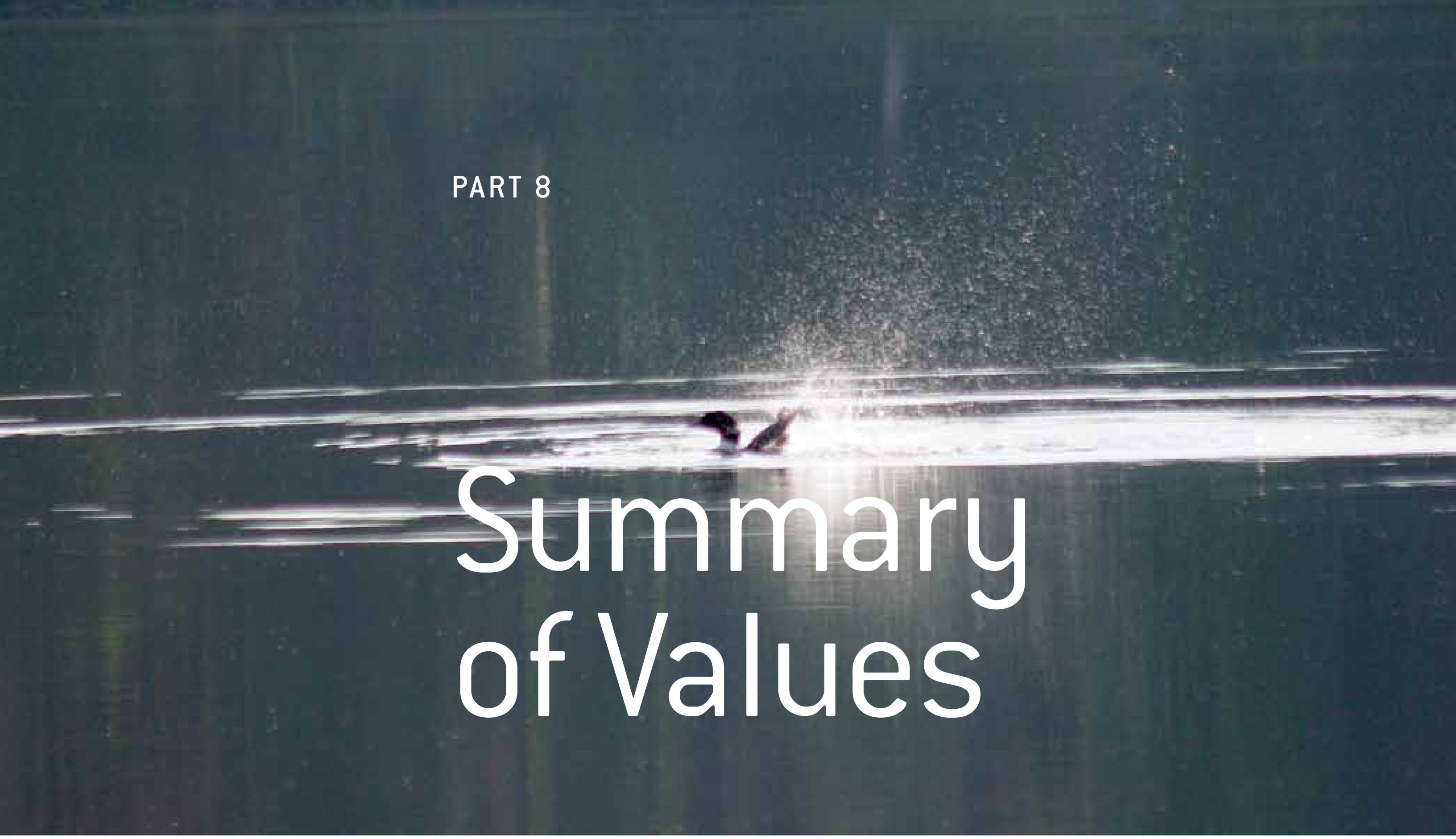
97 Dale, V.H., and Polasky, S. 2007. "Measures of the effects of agricultural practices on ecosystem services." *Ecological Economics*. Doi:10.1016/j.ecolecon.2007.05.009; Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., and Polasky, S. 2002. "Agricultural sustainability and intensive production practices. *Nature*. 418: 671-677; Swinton, S.M., Lupi, F., Robertson, G.P., and Hamilton, S.K. 2007. "Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits." *Ecological Economics*. Doi:10.1016/j.ecolecon.2007.09.020.

98 Sandhu, H.S., Wratten, S.D., Cullen, R., and Case, B. 2008. "The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach." *Ecological Economics*. 64:835-848.

99 2009 State of the Fraser Basin Report: Sustainability Snapshot 4. The Many Faces of Sustainability. Fraser Basin Council. Vancouver, B.C. (www.fraserbasin.bc.ca)

100 OMAFRA staff. Ontario Ministry of Agriculture, Food and Rural Affairs. (last reviewed: May 3, 2007). www.omafra.gov.on.ca/english/crops/organic/faq.htm (accessed March 17, 2008).

101 MacRae, R. et al. 2006. *Ontario Goes Organic: How to access Canada's growing billion dollar market for organic food*. World Wildlife Fund and Organic Agriculture Centre of Canada. (Version 4, June 26, 2006).



PART 8

Summary of Values

The top three greatest values in terms of benefit types are water supply (i.e., water filtration services by forests), climate regulation and flood protection/ water regulation.

VALUE OF ECOSYSTEM SERVICES BY BENEFITS

The top three greatest values in terms of benefit types are water supply (i.e., water filtration services by forests), climate regulation and flood protection/water regulation (Table 12). The total value for climate regulation is an estimated $1.7 billion for all land-cover types, water supply is an estimated $1.6 billion, and flood protection/water regulation benefit is an estimated $1.2 billion (Table 12). If all benefit values are added up, then the total value for the study area is an estimated $5.4 billion per year or an estimated average of $3,958 per hectare.[102] Analysis of the 2006 census reports that 2.2 million people live within the study area.[103] Thus, the value per capita is $2,449 and the estimated value per household is $6,368 each year.[104]

VALUE OF ECOSYSTEM SERVICES BY LAND COVER CLASS

The benefits can also be calculated by land cover class or ecosystem type. Forests and wetlands have the greatest benefit values with forests estimated at $5.1 billion ($5,900 to $7,400/hectare), and wetlands worth an estimated $127 million (ranging from $4,017 to $6,996 per hectare). The values by land cover class or ecosystem type are shown in Table 13.

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102 Average value per hectare was calculated as total value divided by total study area (hectares).

103 2006 census data was extracted for the study area. The results show 2,194,377 in the primary study area, and the combined population for primary and secondary areas is 2,197, 918.

104 Number of households is estimated based on total population from 2006 census, assuming that there are approximately 2.6 people on average per household.

TABLE 12: SUMMARY OF VALUE OF ECOSYSTEM SERVICES BY BENEFIT (2005$)

Benefits	Land cover type	Total value millions$	Value per hectare ($/ha)
Climate regulation	Forests (primary study area)	$246	$1,709
	Forests (secondary study area)	$1,280	$1,898
	Wetlands	$44	$1,432
	Grasslands	$3.1	$594
	Shrublands	$61	$1,000
	Croplands	$41	$698
Clean air	Forests	$409	$495
Coastal protection	Marshes	n/a	n/a
Flood protection/ water regulation	Forests	$1,241	$1,502
Waste treatment	Wetlands	$41	$1,283
Water supply	Forests	$1,561	$1,890
	Wetlands	$61	$1,890
Pollination	Forests (primary study area)	$234	$1,669
	Shrublands (primary study area)	$14	$1,669
	Grasslands (primary study area)	$0.1	$1,669
Salmon habitat	Integral forests	$1.6	$3
Recreation/tourism	Forests	$105	$127
	Wetlands	$4.1	$127
	Farm-based	$13	$422
Local food production	Croplands	$24	$382
Total		$5,384	

TABLE 13: SUMMARY OF VALUE OF ECOSYSTEM BENEFITS BY LAND COVER

Land cover type	Total value millions$	Value per hectare ($/ha)
Forests (primary study area)	$1,041	$7,432
Forests (secondary study area)	$4,055	$5,913
Bogs	$12	$5,996
Swamps	$8	$4,796
Fens	$12	$4,777
Shallow water wetland	$48	$4,017
Marsh	$14	$4,366
Other wetland	$34	$4,437
Grasslands (primary study area)	$0.1	$2,262
Grasslands (secondary study area)	$3	$594
Shrublands (primary study area)	$22	$2,669
Shrublands (secondary study area)	$53	$1,000
Agriculture	$44	$698
Integral forests (only forests >100 yrs old)	$1.6	$3
Farm-based recreation	$13	$422
Local food production	$24	$382
Total	$5,384	

Natural capital does not depreciate over time because it is self-maintained, and it can be argued that in the future natural capital will be worth more – not less – because as the population grows, our remaining natural capital will become more valuable.

NET PRESENT VALUES FOR ECOSYSTEM BENEFIT VALUES

The net present value can be calculated for a specific time period using different discount rates. We have used a 50-year period because this is a typical time period used for manufactured capital. Discount rates are commonly used to assess the economic benefits of investment for decision-making. Values or benefits are discounted over time to reflect: 1) that people generally value immediate benefits over benefits in the future; and 2) manufactured capital depreciates over time resulting in lower values in the future. The use and rate of discount rates for natural capital has been debated in academic literature, however, there is no clear resolution yet on how to treat natural capital.

Natural capital does not depreciate over time because it is self-maintained, and it can be argued that in the future natural capital will be worth more – not less – because as the population grows, our remaining natural capital will become more valuable. This will result from potentially less natural capital available due to the current rate of loss in capital and degradation due to the impacts of population growth. It is important to note that if natural capital were to increase in value over time, then a negative discount rate would be used to capture the net present value.

We have therefore chosen a range of discount rates. A zero per cent discount rate represents the fact that natural capital does not depreciate over time; a 3 per cent discount rate is commonly used in socio-economic studies, and a 5 per cent discount rate is a more conventional rate. Over a 50-year period, the net present value is $270 billion at a 0 per cent discount rate ($198,547/hectare), $139 billion at a 3 per cent discount rate ($102,215/hectare), and $96 billion at a 5 per cent discount rate ($70,594/hectare). Table 14 shows the net present values by discount rates and values per capital and household.

TABLE 14: NET PRESENT VALUES FOR ECOSYSTEM BENEFITS (2005$)

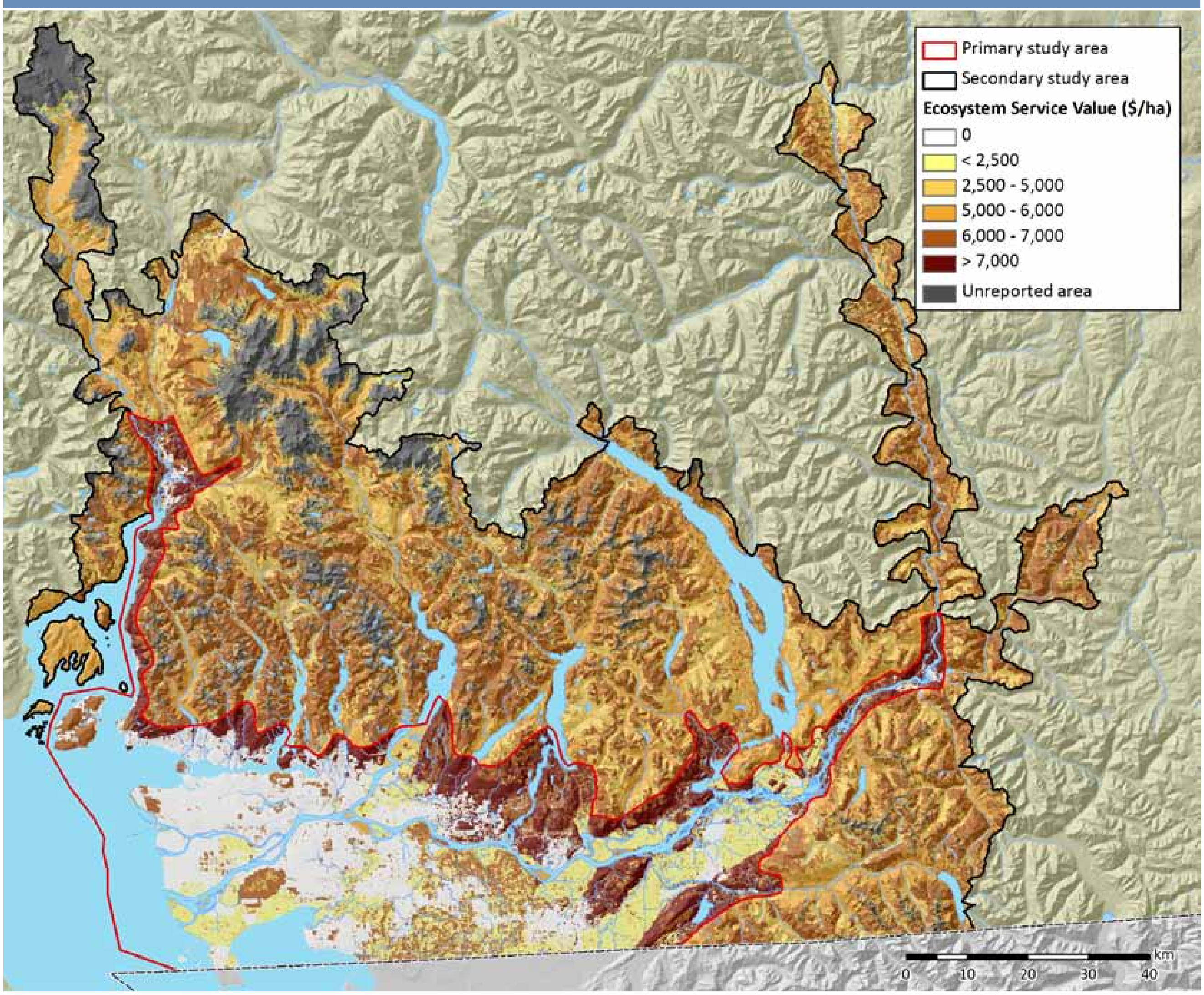
Discount rate	Net present value (50-year period) billions$	Value per capita	Value per household
0%	270	$122,844	$319,393
3%	139	$63,242	$164,428
5%	96	$43,678	$113,562

DISTRIBUTION OF ECOSYSTEM BENEFITS BY WATERSHED

Analysis was undertaken to shown the distribution of ecosystem benefits across the study area. The annual value per hectare for each land cover class type was used to assess the average values at the landscape and watershed level. The average annual values across the study area range from $0 to greater than $7,000 per hectare (Map 10). The values are highest for the immediate watershed areas above Metro Vancouver and the Fraser Valley, as well as the wetlands within the Fraser Valley lowlands. The lowest values are the developed areas of Metro Vancouver and within the primary study area. The watersheds in the secondary study area have high average values within the range of $4,000 to $6,000 per hectare. The unreported areas illustrate exposed land and snow cover that were not valued in this report.

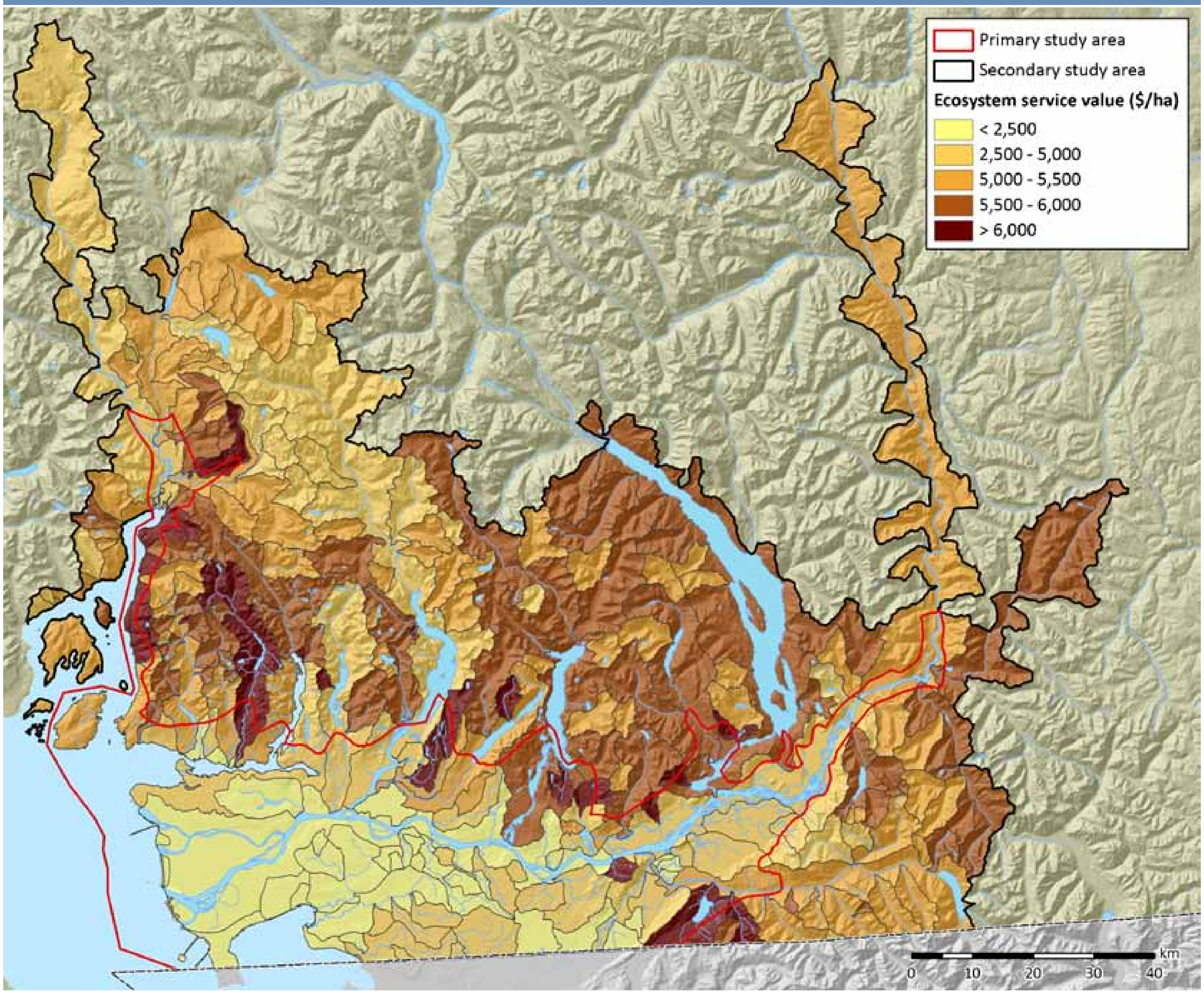
The average values by watershed unit were also assessed to illustrate the range of value across the watersheds within the study area. The values ranged from $0 to over $7,000 per hectare. The lower values associated with the developed areas of the primary study area are illustrated in this

MAP 10: AVERAGE ANNUAL ECOSYSTEM VALUES



map similar to Map 10. However, a wide range of values across the secondary study area is also shown by the watershed average values (Map 11). The darkest brown colour areas indicate the higher values. These areas are located in parts of the watersheds in the secondary study area as well as along the upper Fraser River.

MAP 11: AVERAGE ANNUAL ECOSYSTEM VALUES BY WATERSHED UNIT



Average values were also assessed for the larger watersheds within the study area. There are five major watersheds (Map 12). Harrison River watershed had the highest annual value estimated at $5,531 per hectare, followed by the Fraser Canyon watershed ($5,278 per hectare), the Squamish watershed ($4,862 per hectare), the Chilliwack River watershed ($4,660 per hectare), and the Lower Fraser ($4,021 per hectare) (Table 15). However, if the watershed groups are split between the primary study area and the secondary study area (watersheds), the average ecosystem service benefit values range from $3,458 to $6,334 per hectare by watershed group in the primary study area, and from $5,264 to $5,551 per hectare by watershed group in the secondary study area.

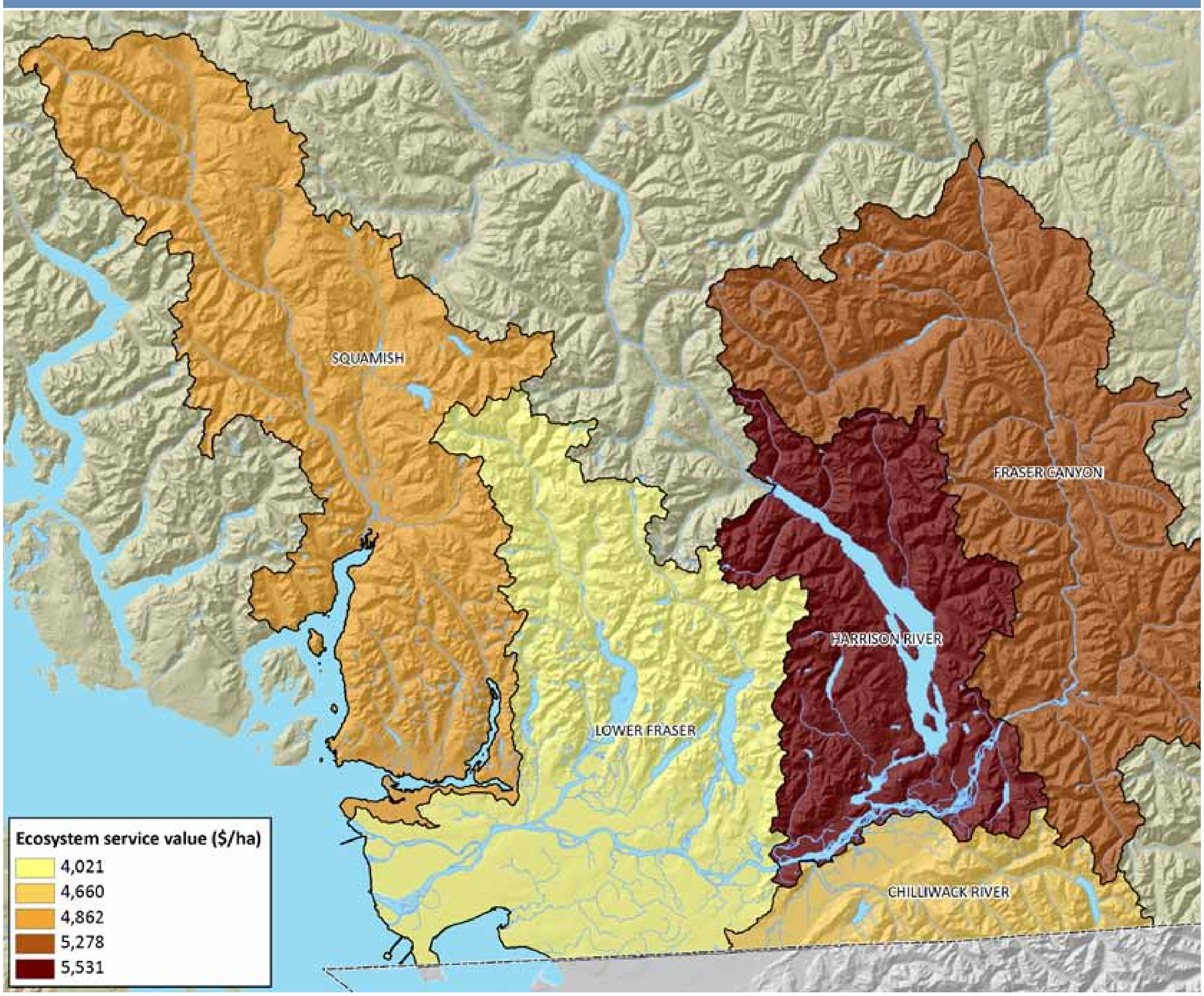
TABLE 15: AVERAGE ECOSYSTEM SERVICE BENEFIT VALUES BY WATERSHED GROUP

	Average Ecosystem Services Value ($/ha)	
Watershed Group	Primary Study Area	Secondary Study Area
Chilliwack River	3,457.6	5,488.5
Fraser Canyon	6,333.8	5,410.5
Harrison River	5,329.1	5,551.3
Lower Fraser	2,833.4	5,380.4
Squamish	4,324.6	5,263.9

The average value per hectare by community watershed was an estimated $6,434. Metro Vancouver's community watersheds showed average values just below the average. Seymour community watershed had an estimated $5,910 per hectare, and the Capilano community watershed showed an estimated $5,819 per hectare, based on the average values by land cover type.

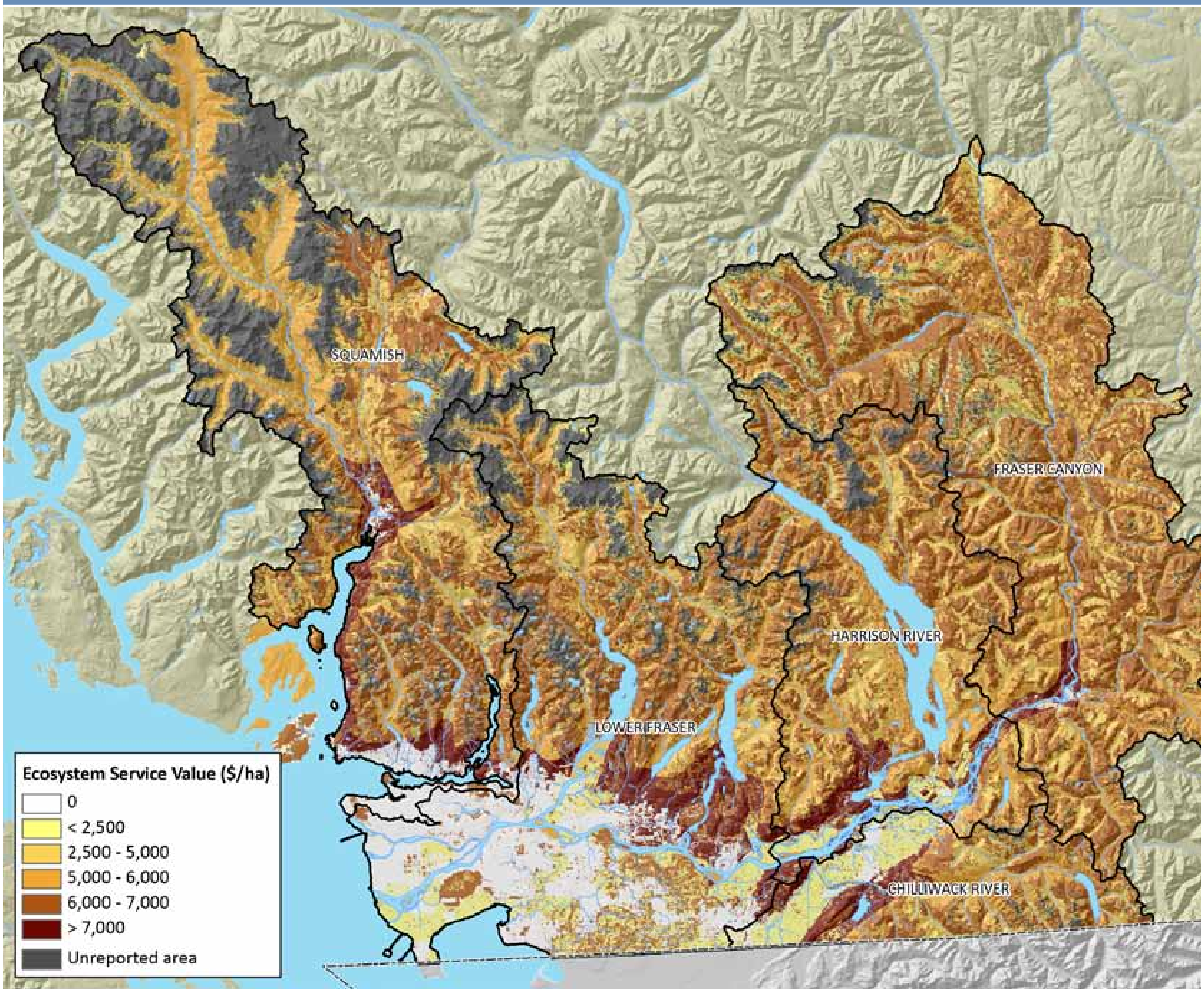
The average value per hectare by community watershed was an estimated $6,434.

MAP 12: AVERAGE ANNUAL ECOSYSTEM VALUES BY WATERSHED GROUP



The average ecosystem values were then applied to the entire watershed groups covered in the study area. Map 13 shows the average values for the entire watersheds.

MAP 13: AVERAGE ANNUAL ECOSYSTEM VALUES ACROSS ENTIRE WATERSHEDS



Conclusions

BRITISH COLUMBIANS IN THE LOWER MAINLAND have been blessed with a staggering wealth of natural capital. Its natural areas provide numerous ecosystem services that are essential to local communities, as well as regional and global processes. These services include fresh water supply, water regulation, clean air, wildlife habitat, climate regulation, food production, and recreational activities. However, like much of the world's urban areas, the region's rapid population growth and sprawling towns and cities continue to exert pressure on its natural capital and the essential services it provides.

As the region's population is expected to grow to more than 3 million residents by 2020, the strain on natural capital will likely become even more intense, especially if current low density-type development continues. For example, studies show that for every 1,000 new inhabitants in the region, 28 hectares of land are converted for urban land use.[105] At current population growth rates, 28,000 hectares of land will be consumed by 2026 if low-density development continues. This is equivalent to 17 per cent of the remaining non-developed land base, and 28 per cent of what remains on the Fraser Valley floor in the GVRD. If we apply the estimated average value for natural capital per hectare ($3,958/hectare), then a loss of 28,000 hectares would incur a loss of over $110.8 million.

This report examines the extent of the region's natural capital – its forests, fields, wetlands and waterways –and for the first time estimates an economic value for the various services and benefits these ecosystems provide. The total value for the study area, which includes the Lower Fraser Valley and its upper watersheds, is an estimated $5.4 billion per year in benefits from its natural capital, or about $3,958 per hectare. The average household income in Greater Vancouver is approximately $75,000. Therefore, the value of benefits per household from natural capital ($6,368) is equal to about 8.5 per cent of the average household in the region[106] Over a 50-year period, the net present value of the region's natural capital benefits are estimated at $270 billion at a zero per cent discount rate, $139 billion at a 3 per cent discount rate, and $96 billion at a 5 per cent discount rate. The net present value per household would then range from about $113,560 to $319,390.

The total value for the study area, which includes the Lower Fraser Valley and its upper watersheds, is an estimated $5.4 billion per year in benefits from its natural capital.

The intent of the report is to provide a preliminary assessment of ecosystem services in economic terms so decision makers and the public can appreciate the true cost of degrading our ecosystems and, conversely, the potential economic benefits of protecting and restoring the region's wealth of natural capital.

It is our hope that this report will encourage discussion about how we value – and undervalue – natural capital in and around our cities. We encourage decision makers and the public to use this report, and other natural capital valuations to inform discussion on how to best protect and restore the region's precious natural capital and ensure a sustainable future.

105 Ibid.

106 2006 Census Profile. Greater Vancouver. BC Stats. Source: Statistics Canada, Census of Population and Housing. www.bcstats.gov.bc.ca/data/cen06/profiles/detailed/59015000.pdf

PART 9

Limitations of Study and Results

Although the methodologies are not yet perfected, it is still better to have approximate average values than to assign a value of zero when designing policy or making land-use planning decisions.

THIS STUDY PROVIDES PRELIMINARY ESTIMATE values for the benefits provided by ecosystem services in the study area, which includes the Lower Mainland and its associated watersheds. It was not possible to evaluate all ecosystem services with a monetary value because of incomplete socio-economic information. In addition, the values reported (except for forest carbon storage, where forest age was used to asses storage capability), assume that each land cover type provides the same flow of ecosystem services.

This study focused on terrestrial-based ecosystem values and therefore excludes the substantial values that are associated with the Fraser River, the Fraser River estuaries and the coastal, near-shore and marine values. The only value included at this stage of assessment was the estimated value for carbon sequestration by tidal wetlands. These values would add tremendous value to the region's natural capital. A study is currently being planned to assess these values and will be released some time in the future.

The lack of information on the current state of ecosystems posed limitations on the calculation of the current values. Therefore, the results presented here are a first approximation of the economic value of the ecosystem services provided by nature in the study area. The lack of data and socio-economic information places a huge limitation on the progress of natural capital accounting and the financial implications of unsustainable land use and pollution.

Although the natural capital valuation methodologies are still being developed, it is still better to have approximate average values than to assign a value of zero when designing policy or making land-use planning decisions. Based on thorough literature review and the application of local data and relevant economic valuation methods, we are confident that the estimates are meaningful. However, this report is intended to provide a foundation in the process of natural capital accounting and ecosystem service valuation and monitoring for the region.

Ultimately, the estimated benefits provided are likely a conservative estimate, due to our incomplete understanding of *all* the benefits provided by nature, the intrinsic value of nature itself and the likely increase in ecosystem service value over time, as services such as water supply become increasingly scarce due to global warming. The ecosystem service values, however, provide an opportunity to rigorously assess the current benefits of the Lower Mainland and its associated watersheds, as well as the potential costs of land use change.

APPENDIX A

Land Cover Sources

Land Cover Mapping for Agricultural Regions, circa 2000

Agriculture and Agri-Food Canada

A thematic land cover classification representative of circa 2000 conditions for agricultural regions of Canada. Land cover is derived from Landsat5-TM and/or 7-ETM+ multi-spectral imagery by inputting imagery and ground reference training data into a Decision-Tree or Supervised image classification process. Object segmentation, pixel filtering, and/or post editing is applied as part of the image classification. Mapping is corrected to the GeoBase Data Alignment Layer. National Road Network (1:50,000) features and other select existing land cover products are integrated into the product. UTM Zone mosaics and National Topographic Series map sheet (1:250,000) tiles are generated from individual 30 metre resolution classified scenes. A spatial index is available indicating the Landsat imagery scenes and dates input in the classification

This product is published and compiled by Agriculture and Agri-Food Canada (AAFC), but also integrates products mapped by other provincial and federal agencies; with appropriate legend adaptations. This is an interim release including UTM Zones 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, and 22 for corresponding agricultural regions in Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta and BC covering approximately 370,000,000 hectares of mapped area.

Mapped classes include: Water, Exposed, Built-up, Shrubland, Wetland, Grassland, Annual Crops, Perennial Crops and Pasture, Coniferous, Deciduous and Mixed forests. However, emphasis is placed on accurately delineating agricultural classes, including: annual crops (cropland and specialty crops like vineyards and orchards), perennial crops (including pastures and forages), and grasslands. Detailed class descriptions and associated digital values are included in the metadata. The geo-spatial data and metadata can be accessed through the GeoConnections Discovery Portal.

http://geodiscover.cgdi.ca/wes/RecordSummaryPage.do?uuid=F1E6A665-C15B-F64B-FC6D-4472BBA89F55&recordLocale=en_US&view=summary&entryPoint=jsMap&mode=unmappable

CWS Fraser Lowlands Wetland Inventory – Lower Mainland (updates from 1999 and 2009)

Wetland Classification – Wetlands of the Fraser Lowlands, 1989: An Inventory – Canadian Wildlife Service (CWS Tech Rep. No.146)

Detailed wetland mapping in the Lower Fraser river. Original survey by Canadian Wildlife Service from 1989 with updates in wetland loss in 1999 (CWS),and 2009 (Metro Vancouver). 2009 update is only available directly from Metro Vancouver.

https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=38766&recordSet=ISO19115

Metro Vancouver Land Use 2006

Only developed land use types were used to create land cover for the study area. Obtained through personal communication with Metro Vancouver staff. www.metrovancouver.org

Soil Landscapes of Canada v3.1.1

SLC v3.1.1 (August 2007) is the latest revision of the Soil Landscapes of Canada, which was developed by Agriculture and Agri-Food Canada to provide information about the country's agricultural soils at the province and national levels. SLC v3.1.1 is a replacement for SLC v3.1.

SLC v3.1.1 provides new soil information at a scale of 1:1 million for the major agricultural regions of Canada. Further releases will provide similar updated information for the rest of the country. The SLC v3.1.1 map series maintains the linkage to the national Ecological Stratification System for Canada. SLC maps are available in several versions (1.0 to 2.2 and now 3.1.1) from the AAFC CanSIS web site.

The Soil Landscapes of Canada Version 3.1.1 has the same GIS polygon coverage as SLCv3.0 and v3.1, representing the major agricultural regions of Canada. Although there are both provincial and national coverages, the SLCv3.1.1 component information is for the agricultural areas of Canada only. An exception to note is that some provinces (i.e. AB, NS, and PEI) contain CMP, SNF and SLF data for the entire province (i.e. beyond the agricultural areas).

http://sis.agr.gc.ca/cansis/nsdb/slc/v3.1.1/intro.html

Soil Organic Carbon Digital Database

Tarnocai, C. and B. Lacelle. 1996. *Soil Organic Carbon Database of Canada*. Eastern Cereal and Oilseed Research Centre, Research Branch. Agriculture and Agri-Food Canada. Ottawa, Canada.

Vegetation Resources Inventory. The B.C. Land Cover Classification Scheme. (2010 update)

Prepared by Ministry of Sustainable Resource Management. Terrestrial Information Branch for the Terrestrial Ecosystems Task Force – Vegetation Resources Inventory Committee. March 29, 2002. Version 1.3. Province of B.C. (annually updated)

Forest vegetation composite polygons: A composite table comprising the polygon table attributes joined to the attributes from the non veg, non tree, land cover component, tree layer, tree species and tree volume tables. This SDE layer coverage contains vegetation cover from the Ministry of Forests. Attribute information is also maintained in this table. It will supersede F_FC. Vegetation Cover is comprised of spatial layers for the collection, manipulation and production of forest inventory data, which has a accompanying textual attributes. This joined table was created to support the Data Distribution Services on the LRDW.

www.for.gov.bc.ca/ric

Baseline Thematic Mapping Present Land Use Version 1

This layer represents Land use polygons as determined by a combination of analytic techniques, mostly using Landsat 5 image mosaics. BTM 1 was done on a federal satellite image base that was only accurate to about 250m. The images were geo-corrected, not ortho-corrected, so there is distortion in areas of high relief. This is not a multipart feature.

https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=43171&recordSet=ISO19115

APPENDIX B

CITYgreen Methods

Stormwater/Runoff Savings

Trees decrease total stormwater volume helping cities to manage their stormwater and decrease detention costs. CITYgreen assesses how land cover, soil type, and precipitation affect stormwater runoff volume. It calculates the volume of runoff in a 2-year, 24-hour storm event that would need to be contained by stormwater facilities if the trees were removed. This volume multiplied by local construction costs calculates the dollars saved by the tree canopy.

CITYgreen uses the TR-55 model developed by the US Natural Resource Conservation Service (NRCS), which is very effective in evaluating the effects of land cover/land use changes and conservation practices on stormwater runoff. The TR-55 calculations are based on a curve number which is an index developed by the NRCS, to represent the potential for storm water runoff within a drainage area. Curve numbers range from 30 to 100. The higher the curve number the more runoff will occur. CITYgreen determines a curve number for the existing landcover conditions and generates a curve number for the conditions if the trees are removed and replaced with the user-defined replacement landcover specified in the CITYgreen preferences. The change in curve number reflects the increase in the volume of stormwater runoff.

Water Quantity (Runoff)

Curve Number using default replacement landcover: 90
Curve Number reflecting existing conditions: 80
2-yr, 24-hr Rainfall: 51.50 mm
Construction cost per cubic. metre.: $57.00
Additional Storage volume needed: 59,445,576 cu. metres (primary area); 249,672,329 cu. metres (total study area)

Percent Change in Contaminant Loadings

Trees filter surface water and prevent erosion, both of which maintain or improve water quality. Using values from the US Environmental Protection Agency (EPA) and Purdue University's L-thia spreadsheet water quality model, American Forests developed the CITYgreen water quality model. This model estimates the change in the concentration of the pollutants in runoff during a typical storm event given the change in the land cover. This model estimates the Event Mean Concentrations of Nitrogen, Phosphorus, Suspended Solids, Zinc, Lead, Copper, Chemical Oxygen Demand (COD), and

Biological Oxygen Demand (BOD). Pollutant values are shown as a percentage of change when the landcover is altered. No valuation is provided for these benefits.

Biological Oxygen Demand 42.18
Chemical Oxygen Demand 65.04
Copper 34.08
Lead 18.38
Nitrogen 24.16
Phosphorus 47.98
Suspended Solids 41.69
Zinc 13.42

Air Pollution Removal

By absorbing and filtering out nitrogen dioxide (NO2), sulfur dioxide (SO2), ozone (O3), carbon monoxide (CO), and particulate matter less than 10 microns (PM10) in their leaves, urban trees perform a vital air cleaning service that directly affects the well-being of urban dwellers. CITYgreen estimates the annual air pollution removal rate of trees within a defined study area for the pollutants listed below. To calculate the dollar value of these pollutants, economists use "externality" costs, or indirect costs borne by society such as rising health care expenditures and reduced tourism revenue. The actual externality costs used in CITYgreen are reported by the United States Public Services Commission. An average of each state in the US is used and the dollar value conversion is $1US = $1.11CAN (Nearest Air Quality Reference City: Seattle, WA).

The Air Pollution Removal program is based on research conducted by David Nowak of the USDA Forest Service. Dr. Nowak developed a methodology to assess the air pollution removal capacity of urban forests with respect to pollutants such as nitrogen dioxide (NO2), sulfur dioxide (SO2), ozone (O3), carbon monoxide (CO), and particulate matter less than 10 microns (PM10). Pollution removal is reported on an annual basis in pounds and U.S. dollars.

Dr. Nowak estimated removal rates for 10 cities: Atlanta, Georgia; Austin, Texas; Baltimore, Maryland; Boston, Massachusetts; Denver, Colorado; Milwaukee, Wisconsin; New York, New York; Philadelphia, Pennsylvania; St. Louis, Missouri; and Seattle, Washington. Average results from all 10 cities were used in our analysis.

The program estimates the amount of pollution being deposited within a certain given study site based on pollution data from the nearest city then estimates the removal rate based on the area of tree and/or forest canopy coverage on the site.

References: Atlanta, GA: Nowak, D.J. and Crane, D.E. 2000. The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions. In M. Hansen and T. Burk, eds. Proceedings: Integrated tools for natural resources inventories in the 21st century. IUFRO Conference, 16-20 August 1998, Boise, ID; General Technical Report NC-212, U.S. Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN. pp. 714-720.

Carbon Sequestration

CITYgreen's carbon module quantifies the role of urban forests in removing atmospheric carbon dioxide and storing the carbon. Based on tree attribute data on trunk diameter, CITYgreen estimates the age distribution of trees within a given site and assigns one of three age distribution types. Type I represents a distribution of comparatively young trees. Type 2 represents a distribution of older trees. Type 3 describes a site with a balanced distribution of ages. Sites with older trees (with more biomass) are assumed to remove more carbon than those with younger trees (less biomass) and other species. For forest patches, CITYgreen relies on attribute data on the dominant diameter class to calculate carbon benefits.

Each distribution type is associated with a multiplier, which is combined with the overall size of the site and the site's canopy coverage to estimate how much carbon is removed from a given site. The program estimates annual sequestration, or the rate at which carbon is removed, and the current storage in existing trees. Both are reported in tons. Economic benefits can also be associated with carbon sequestration rates using whatever valuation method the user feels appropriate. Some studies have used the cost of preventing the emission of a unit of carbon – through emission control systems or "scrubbers," for instance – as the value associated with trees' carbon removal services.

Technical Methodology

Estimating urban carbon storage and sequestration requires the study area (in acres), the percentage of crown cover, and the tree diameter distribution. Multipliers are assigned to three predominant tree diameter distribution types:

Distribution Types Carbon Sequestration Multipliers

Type 1 (Young population) 0.00727
Type 2 (Moderate age population, 10-20 years old) 0.00077
Type 3 (Even distribution of all classes) 0.00153
Average (Average distribution) 0.00335

CITYgreen uses these multipliers to estimate carbon storage capacity and carbon

sequestration rates. For example, to estimate carbon storage in a study area: *Study area (acres) x Percent tree cover x Carbon Storage Multiplier = Carbon Storage Capacity*

To estimate carbon sequestration: *Study area (acres) x Percent tree cover x Carbon Sequestration Multiplier = Carbon Sequestration Annual Rate*

References:

1. Nowak, David and Rowan A. Rowntree. "Quantifying the Role of Urban Forests in Removing Atmospheric Carbon Dioxide." Journal of Arboriculture, 17 (10): 269 (October 1, 1991).

2. McPherson, E. Gregory, Nowak, David J. and Rowan A. Rowntree, eds. 1994. "Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project." Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern

APPENDIX C

Definition and Identification for Ecosystem Services

The following tables were used to identify the potental types of ecosystem services provided the land cover types in the Lower Mainland and upper watersheds. The potential services were then identified as benefits using the TEEB typology and streamlined according to those that could be readily identified, measured and valued.

ECOSYSTEM FUNCTIONS, PROCESSES AND CORRESPONDING ECOSYSTEM SERVICES

Functions	Ecosystem Processes or Components	Ecosystem Services
Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO2/O2 balance, ozone layer)	UVb protection by ozone, maintenance of air quality
Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favourable climate, carbon regulation, cloud formation
Disturbance prevention	Influence of ecosystem structure on environmental disturbances	Storm protection, flood control, drought recovery
Water regulation	Role of land cover in regulating runoff and river discharge	Drainage, natural irrigation, transportation
Water supply	Filtering, retention and storage of fresh water	Provision of water by watersheds, reservoirs and aquifers
Soil retention	Role of the vegetation root matrix and soil biota in soil retention	Prevention of soil loss/damage from erosion/ siltation; storage of silt in lakes, and wetlands; maintenance of arable land
Soil formation	Weathering of rock, accumulation of organic matter	Maintenance of productivity on arable land; maintenance of natural productive soils
Nutrient cycling	Role of biota in storage and re-cycling of nutrients (e.g. nitrogen)	Maintenance of healthy soils and productive ecosystems; nitrogen fixation
Waste treatment	Role of vegetation and biota in removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification, filtering of dust particles, abatement of noise pollution
Pollination	Role of biota in the movement of floral gametes	Pollination of wild plant species and crops
Biological control	Population and pest control	Control of pests and diseases, reduction of herbivory (crop damage)
Habitat	Role of biodiversity to provide suitable living and reproductive space	Biological and genetic diversity, nurseries, refugia, habitat for migratory species
Food production	Conversion of solar energy, and nutrient and water support for food	Provision of food (agriculture, range), harvest of wild species (e.g. berries, fish, mushrooms)
Raw materials	Conversion of solar energy, nutrient and water support for natural resources	Lumber, fuels, fodder, fertilizer, ornamental resources

Functions	Ecosystem Processes or Components	Ecosystem Services
Genetic resources	Genetic materials and evolution in wild plants and animals	Improve crop resistance to pathogens and crop pests, health care
Medicinal resources	Biochemical substances in and other medicinal uses of biota	Drugs and pharmaceuticals, chemical models & tools
Recreation	Variety in landscapes	Ecotourism, wildlife viewing, sport fishing, swimming, boating, etc.
Education, Culture & Spirituality	Variety in natural landscapes, natural features and nature	Provides opportunities for cognitive development: scenery, cultural motivation, environmental education, spiritual value, scientific knowledge, aboriginal sites

Source: Wilson, S. 2008. *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Services*. David Suzuki Foundation. Vancouver, Canada. Adapted from: De Groot, R.S., 2002. "A typology for the classification, description and valuation of ecosystem functions, goods and services." *Ecological Economics*. 41: 393-408.

ECOSYSTEM SERVICES AND POTENTIAL BENEFITS/VALUES BY ECOSYSTEM TYPE FOR THE LOWER MAINLAND STUDY

Biome Type/Ecosystem	Ecosystem Services (Typology of ES from TEEB)	Potential Benefits for Human Well-being
Coastal Systems	Geodynamics, sediment and nutrient cycling/transport Primary production Water cycling Climate mitigation	Storm protection, flood/storm buffering, drought recovery Shoreline stabilization Maintenance of a favourable climate, carbon regulation, cloud formation Ecosystem stability/resilience Waste processing Erosion control Freshwater storage Amenity, tourism, and recreation provision Cultural/heritage conservation
Wetlands	Provision of habitat for pollinators for wild plant species and crops Filtering, retention and storage of fresh water Regulation of water flows Waste treatment Carbon sequestration/storage	Food provision Maintenance of a favourable climate, carbon regulation Flood control Waste processing Water supply Amenity, tourism, and recreation provision Cultural/heritage conservation
Lakes & Rivers	Regulation of water flows Waste treatment Maintenance of life cycles of migratory species Maintenance of genetic diversity	Drainage and natural irrigation Transportation Prevention of soil loss/damage from erosion/ siltation; storage of silt in lakes Recreation and amenity Inspirational, educational and spiritual experience Food provision Water supply Genetic resources Amenity, tourism, and recreation provision Cultural/heritage conservation

Biome Type/Ecosystem	Ecosystem Services (Typology of ES from TEEB)	Potential Benefits for Human Well-being
Forests Temperate mixed forest Cool coniferous forest	Biological and genetic diversity, nurseries, refugia, habitat for migratory species Pollination of wild plant species and crops Air quality regulation Climate sequestration/storage Regulation and filtration of water flows Erosion prevention Maintenance of soil fertility and soil development Biological control (e.g. forest birds)	Maintenance of air quality Provision of filtered water by forests through watersheds, reservoirs and aquifers quality Maintenance of a favourable climate, carbon regulation Control of pests and diseases, reduction of herbivory (crop damage) Harvest of wild species (e.g. berries, fish, mushrooms) Biological and genetic diversity, nurseries, refugia, habitat for migratory species Amenity, tourism, and recreation provision Cultural/heritage conservation
Woodland & Shrubland	Biological and genetic diversity, nurseries, refugia, habitat for migratory species Pollination of wild plant species and crops Air quality regulation Climate sequestration/storage Regulation and filtration of water flows Erosion prevention Maintenance of soil fertility and soil development Biological control (e.g. forest birds)	Biological and genetic diversity, nurseries, refugia, habitat for migratory species Maintenance of a favourable climate, carbon regulation Harvest of wild species (e.g. berries, fish, mushrooms) Amenity, tourism, and recreation provision Cultural/heritage conservation
Grass & Rangeland	Biological and genetic diversity, nurseries, refugia, habitat for migratory species Pollination of wild plant species and crops Air quality regulation Climate sequestration/storage Regulation and filtration of water flows Erosion prevention Maintenance of soil fertility and soil development Biological control (e.g. birds)	Maintenance of a favourable climate, carbon regulation Food provision Flood control Erosion control Air quality Amenity, tourism, and recreation provision Cultural/heritage conservation
Ice/Rock	Biological and genetic diversity, nurseries, refugia, habitat for migratory species Climate mitigation/regulation Regulation of water flows Primary production	Maintenance of a favourable climate, carbon regulation Amenity, tourism, and recreation provision Cultural/heritage conservation
Cultivated Areas	Pollination Carbon sequestration/storage Erosion prevention Maintenance of soil fertility and soil development/Loss of soil fertility and soil	Provision of food (agriculture) Pollination of crops Amenity and recreation provision Cultural/heritage conservation
Green Urban Areas	UVb protection by ozone (if ozone intact) Pollination of plants Pollution control/detoxification, filtering of dust particles	Abatement of air and noise pollution Property enhancement Inspiration, and spiritual enhancement Amenity, tourism, and recreation provision Cultural/heritage conservation

This report examines the extent of natural capital – forests, fields, wetlands and waterways – in BC's Lower Mainland region and estimates non-market economic values for some of the benefits these ecosystems provide. The intent of the report is to provide a preliminary assessment of these ecosystem service benefits to better inform future discussion about how to protect and restore the region's precious natural capital and ensure a sustainable future.

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