EXTENDING THE FUNDING CANOPY

A GUIDEBOOK ON ESTIMATING THE ECONOMIC VALUE OF NATURE-BASED SOLUTIONS

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Smart Prosperity Institute

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EXECUTIVE SUMMARY

Investing in conservation and restoration of nature and in sustainable resource management should be a central components of a resilient economic recovery. These investments create economic value and jobs and are critical to meeting Canada's climate change and biodiversity objectives. However, there are barriers to public and private financing of these projects which mean that they receive less financing than would be justified by their potential economic contributions, not to mention their environmental and social benefits. One such barrier is the fact that practitioners proposing projects that offer nature-based solutions (NBS) to problems like climate change or water management often lack the capacity and data to make an economic case for their projects. This puts them at a disadvantage as they compete for funding with technology-based solutions that tend to have better access to data and familiarity with methods to estimate their project's impact on revenue streams, cost savings, jobs, and economic output.

This guidebook aims to remove this barrier by helping NBS practitioners[1] make an economic case for NBS projects. We discuss simple, publicly accessible methods for estimating 1) revenue streams and cost savings due to increased ecosystem services, and 2) impacts on local jobs and economic output.

We also discuss ways public data sources could be improved to make it easier to estimate the economic case for NBS. Finally, we make the economic case for four case studies: a wetland restoration project in rural Ontario, a mixed-use forestry and conservation project in British Columbia, a low-tillage potato farming operation on Prince Edward Island, and a protected area in the Northwest Territories.

We find that:

1) NBS projects produce substantial economic benefits, even by our conservative definition which focuses on revenue streams, cost savings, and impacts on jobs and economic output.

2) When estimating revenue and cost savings from enhanced ecosystem services, transferring estimates (aka "value transfer") from other projects can lead to important errors, despite being common practice. That said, value transfer can be helpful if done carefully. NBS practitioners can avoid major inaccuracies by following a few best practices:

- The revenue and cost savings from ecosystem services depend on site size and surrounding land uses. Adjusting transferred values based on these factors can make estimates more accurate.

- Project impacts on local jobs and economic output depend on the structure of the local economy and on a project's inputs. It is better to make a crude estimate with project-specific data than to transfer a sophisticated estimate from a different context. If you do transfer an estimate, it is more important to find an estimate from a project in a similar economic context and with similar labour requirements than to find an estimate from a project in a similar ecological context.

NBS projects produce substantial economic benefits, even by our conservative definition.

3) Government agencies could make it easier to estimate the business case for NBS projects by filling gaps in publicly accessible data sources. For example:

    - Statistics Canada's input-output multipliers, which can be used to estimate project impacts on jobs and economic output, use categories of economic activity that do not correspond well with the typical expenditures of NBS projects.

    - Biophysical and economic data that are needed to estimate the value of important ecosystem services are not yet publicly available. For example:

        - Federal and provincial governments should support the collection of more data on carbon stocks and fluxes in unmanaged forests and areas with non-forest vegetation, particularly peatlands, and make this data available in an integrated, spatially-explicit format that is accessible to non-expert NBS practitioners. Better data on wetland characteristics would also help NBS practitioners estimate the value of other ecosystem services, like nutrient removal.

        - Treatment plants that remove nutrients like phosphorus and nitrogen from runoff and wastewater should make their unit removal costs public. This would allow NBS practitioners (and, ideally, municipal asset planners) to estimate the value of NBS projects that can remove these nutrients.

        - More up-to-date, region-specific data is needed on the cost to farmers of soil erosion.

        - The 2012 Canadian Nature Survey provides useful estimates of expenditures on nature-related recreation and tourism, but these estimates are now out of date, and they are not regionally specific.

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LIST OF ABBREVIATIONS

BMP	Beneficial management practice
CC	Cover crop
CGE	Computable general equilibrium
CH_4	Methane
CICES	Common International Classification of Ecosystem Services
CO_2	Carbon dioxide
CO_2e	Carbon-dioxide-equivalent
DUC	Ducks Unlimited Canada
EPA	US Environmental Protection Agency
ES	Ecosystem service
GDP	Gross domestic product
GHG	Greenhouse gas
GWP	Global warming potential
HSIs	Habitat suitability indices
I-O	Input-output
IOIC	Input-Output Industry Classification System
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
MBCA	Mount Broadwood Conservation Area
MEA	Millennium Ecosystem Assessment
NBS	Nature-based solutions
NCC	The Nature Conservancy of Canada
NESCS Plus	National Ecosystem Services Classification System Plus
N_2O	Nitrous oxide
PEIFA	Prince Edward Island Federation of Agriculture
RUSLEFAC	Revised Universal Soil Loss Equation for Application in Canada
SCC	Social cost of carbon
SGWP	Sustained-flux global warming potential
TBS	Technology-based solutions
TEEB	The Economics of Ecosystems and Biodiversity
TNNPR	Thaidene Nëné National Park Reserve
$	2021 Canadian Dollars (CAD) unless otherwise specified

1. INTRODUCTION

There is an economic case for investing in nature…

Conservation, restoration, and improved resource management (see Box 1) have traditionally been financed by public and philanthropic funds because of the environmental and social benefits of these activities. This public and philanthropic funding is indispensable, but, unfortunately, it is currently insufficient to address the many problems caused by environmental degradation. For example, the global shortfall in financing to halt biodiversity decline has been estimated at $700 billion US dollars annually.[2] Fortunately, there is a growing body of evidence that shows how investing in conservation, restoration, and improved resource management can generate concrete revenue and cost savings and create jobs and economic output. These metrics only capture a small fraction of the benefits of investing in nature, but they could unlock new sources of financing, both public and private.

In this report, we aim to help NBS practitioners to expand their financing base by communicating the economic benefits of proposed projects. We refer to conservation, restoration, and improved resource management collectively as nature-based solutions (NBS), since this report is specifically concerned with these activities' capacity to address societal problems such as climate change or water management.

there is a growing body of evidence that shows how investing in conservation, restoration, and improved resource management can generate concrete revenue and cost savings and create jobs and economic output.

NBS projects can contribute to a resilient economic recovery from crises like COVID-19. In the short run, spending on NBS projects can create more local jobs and economic output than other infrastructure projects, because these projects tend to be labour-intensive and use local goods and services as inputs. These jobs can be created quickly and are often in remote or rural areas where jobs are scarce.[3] In the long run, spending on NBS projects can address a variety of problems, including climate change mitigation and adaptation, biodiversity decline, and the spread of infectious diseases, which are devastating communities and ecosystems at tremendous economic cost. A single project can often address many problems: for example, conserving or restoring wetlands can help mitigate climate change by sequestering carbon, help communities adapt to climate change by reducing flooding, and improve water quality by filtering pollutants.

NBS projects can also create revenue streams and cost savings for public and private parties. Municipal governments are a major public beneficiary of NBS projects, as NBS projects can reduce maintenance and capital costs for municipal infrastructure assets. For example, the Municipal Natural Assets Initiative found that seven kilometres of creek-side natural area in the Oshawa Creek Watershed provided the city with storm water conveyance services that would cost $18.9 million if performed by built infrastructure.[4] As for private beneficiaries, the insurance industry is an important example, as upfront investments in NBS projects can reduce the risk of costly payouts following floods or other climate-related disasters.[5]

...but there are barriers to communicating the business case for NBS to funders.

Despite growing evidence that NBS projects can generate cost savings, revenue streams, jobs, and economic output, prospective funders who prioritize these metrics still often overlook NBS projects. For example, even within the portion of COVID-19 recovery spending that has been "green," spending on NBS has been dwarfed by spending on technology-based solutions (TBS).[9] In Canada, the 2021 federal budget committed a landmark $860 million per year to NBS, including investing in natural infrastructure; restoring ecosystems; increasing conserved and protected areas by 1 million square kilometers by 2025; and investing in "climate-smart" agriculture; and a proposal to issue $5 billion in green bonds. The 2021 federal budget also earmarked $1.4 billion per year for TBS to climate change. Both TBS and NBS are important,[10] and Canada has committed a larger proportion of recovery spending to NBS than many other large economies,[11] but Budget 2021 still arguably underfunds NBS given their benefits. In terms of climate change mitigation, NBS investment in Canada could reduce atmospheric greenhouse gases (GHGs) by up to 78.2 megatonnes per year by 2030, with 34% of this available below $50 per tonne, while tree planting could add an additional 24.9 megatonnes per year by 2050.[12] While projections vary, this could contribute 10% of the emissions reductions needed to meet Canada's net zero target. NBS to climate change also bring several "co-benefits" which TBS do not: for example, a pan-Canadian study from 2017 estimated that increased "greenness" in residential areas reduces all causes of mortality, including cardiovascular disease, stroke, and respiratory illnesses, by 8-12%.[13]

Box 1

The definition of conservation is contentious, and changing

The distinction between conservation, restoration, and improved resource management reflects the predominant settler approach to environmentalism. This distinction does not exist in many Indigenous worldviews in what is now called Canada, which typically see humans' use of and relationship to the land as integral to conservation.[6]

This settler distinction has an ugly history. Many settler conservation initiatives have involved the exclusion or forcible removal of Indigenous peoples from their traditional lands. For example, Wood Buffalo National Park severely restricted Indigenous access. Ironically, the rationale was the protection of bison herds, which Indigenous groups had used sustainably for millennia prior to their near extinction at the hands of settlers.[7]

Recently, this settler distinction has begun to blur. Indigenous activism has been instrumental to this process. For example, in 2005, the Mikisew Cree First Nation won the right to hunt, fish, and trap in Wood Buffalo National Park in the Supreme Court. Thaidene Nëné National Park Reserve, created in 2019, is the first national park which incorporates Indigenous use and stewardship by design. The Łutsël K'é Dene have been fighting to realize this vision since 1970.[8] Thaidene Nëné is one of the case studies highlighted in this report.

So why do we still use this distinction between conservation, restoration, and improved resource management in this report? Firstly, because it describes most NBS projects in Canada, by land area and by funding. And secondly, estimating the value of the ecosystem services provided by a given land area is far simpler than estimating the value of ecosystem services associated with a change in management of a given land area. We adopt this distinction pragmatically, in the hope that it will make it easier for NBS practitioners to produce estimates that align with the expectations of potential funders. We hope that this report can be useful to both Indigenous and settler NBS practitioners, despite these simplifications.

The business case for NBS projects is still rarely communicated by NBS practitioners.

One factor hindering the flow of recovery- and clean-growth-focused financing to NBS is the fact that the business case for NBS projects is still rarely communicated by NBS practitioners or understood by prospective funders outside of those who traditionally support NBS. Three examples illustrate this dynamic:

- The Invest in Canada Infrastructure Program has a "green" funding stream that primarily finances water management projects. However, the significant majority of the funding has gone to grey infrastructure – not because natural infrastructure can deliver less ably, but because the economic data needed to compare projects is not readily available for natural infrastructure projects, and the funding criteria did not reward the additional co-benefits that natural infrastructure can deliver.[14]

- In 2020, the Taskforce for a Resilient Recovery made recommendations to the federal government on COVID-19 recovery spending. The Taskforce received a large number of proposals for both NBS and TBS but found that practitioners proposing TBS were more adept at demonstrating that their project could contribute to an economic recovery by creating jobs and economic output – metrics of particular interest to government decision-makers.

- NBS are less likely to be included in green bonds than technological solutions. For example, in 2019, energy, buildings and transport made up 80% of green bonds globally. "Land use" made up only 3.5%.[15]

There are two compelling economic arguments for spending on NBS projects that are still not regularly communicated by NBS practitioners or considered by funders:

- **Revenue streams and cost savings from ecosystem services**: Governments and citizens are increasingly aware of the value of the "ecosystem services'' provided by NBS projects, but in cases where this value translates into revenue streams or cost savings, these are rarely factored into the analyses that determine how funding is allocated. For example, some municipalities are still skeptical of the returns on natural infrastructure projects due to the lack of a standardized approach to estimating these returns.[16]

- **Impacts on jobs and economic output**: Abundant studies show the job creation potential of investments in TBS such as renewable energy projects, but few do so for NBS, particularly in Canada.

There are a few factors that prevent NBS practitioners from communicating the business case for NBS and prevent prospective funders from understanding it:

- **Capacity**: Many NBS practitioners lack the money, time and expertise to use state-of-the-art methods to track, analyze, and model revenue and cost savings arising from improvements in ecosystem health.

- **Data access and availability**: Estimating revenue and cost savings from changes in ecosystem services requires both ecological and economic data, but some of this data is still not publicly accessible in Canada.

- **Weakness of value transfer**: In the absence of capacity and data to do original research, NBS practitioners sometimes use estimates from other projects without adjusting for important differences in context, such as the size of the nearby human population or the structure of the local economy. This makes it hard to interpret and compare estimates.

- **Novelty**: Potential funders are often unfamiliar with the methods used to produce estimates. They can be wary of the widely varying estimates of ecosystem service values they are shown and are unsure how to determine their credibility.[17]

This guidebook is meant to help bridge this gap.

This guidebook aims to help NBS practitioners to make the business case for their projects and to help funders to understand this business case. We focus on a narrow set of economic metrics: jobs, economic output, revenue streams, and cost savings. These metrics do not capture the majority of ecological, social, and economic benefits from NBS projects, such as the continuation of Indigenous peoples' traditional ways of living, the mental health effects of proximity to green space, or the existence of endangered species. In the long term, there is important work to be done to sensitize a broader range of funders to these considerations. But in the meantime, we aim to increase the pool of funding available to NBS projects by helping NBS practitioners speak the language of a set of promising prospective funders who do not yet regularly fund NBS projects. This set of prospective funders includes new players, such as the insurance industry, but also new segments of current NBS funders. For example, the federal government provides substantial funding to NBS through Parks Canada, but far less to Infrastructure Canada, despite growing evidence that natural infrastructure can often do more to advance climate adaptation, mitigation, and community resilience than its grey counterpart.[18]

This guidebook:

- Identifies conservative methods for measuring and communicating the economic case for proposed or completed NBS projects

- Adapts these methods to be accessible to NBS practitioners operating at any scale

- Explains the assumptions, simplifications, and areas of disagreement behind these methods

- Illustrates the application of these methods with case studies

We selected four case studies from across Canada that represent four different types of NBS projects:

- Wetland restoration

- Integrated forestry and conservation areas

- "Climate-smart" agriculture

- Remote protected areas

We chose case studies from these four types of NBS project because they are common, and federal funding priorities indicate there will be increased capacity and support for these types of projects in the near future.[19]

2. USING ECONOMIC METRICS

2.1 Which metrics should you use?

By sustaining healthy ecosystems, NBS projects provide countless benefits to human communities that can be quantified using a vast array of economic and non-economic metrics. This guidebook focuses on quantifying a small subset of these benefits using economic metrics that are of interest to promising prospective funders: 1) revenue streams and cost savings from ecosystem services and 2) project impacts on jobs and economic output. As discussed in the introduction, we focus on these economic metrics not because they are more important than other metrics, but because the aim of this guidebook is to help NBS practitioners expand their pool of prospective funders given the current financing landscape.

Even within this narrow set of metrics, NBS practitioners will need to further tighten their focus due to limited data and capacity. One could estimate endless sources of cost savings associated with a project by exploring different beneficiaries and direct and indirect mechanisms. We recommend focusing on a few key sources of economic benefits that:

- Can be estimated using available data
- Capture large revenue streams, cost savings, or economic impacts
- Are of interest to a promising prospective funder

We focus on these economic metrics not because they are more important than other metrics, but […] to help NBS practitioners expand their pool of prospective funders given the current financing landscape.

In Table 1, we list a few sources of economic benefits which often meet these criteria for NBS projects in Canada. Some of these offer immediate benefits, such as the impacts of project expenditures on jobs and economic output, while others accrue over time as ecosystem health improves.

__Table 1.__ Key sources of revenue, cost savings, and economic impacts from NBS projects in Canada.

Metric	Project type	Beneficiaries
Revenue and cost savings from ecosystem services		
Managed harvests (e.g., timber, crops, livestock)	Forestry, agriculture	Farmers Timber producers
Unmanaged harvests (e.g., cattails, berries)	Forestry, conservation, restoration	Harvesters
Greenhouse gas uptake	All – could refer to offsets generated by soil, avoided deforestation, or forest regeneration	Regulatory or voluntary sellers of offset credits
Avoided water purification or treatment costs	Restoration, conservation, forestry	Municipalities and conservation authorities
New recreation and tourism opportunities	All	Federal and provincial government Municipalities Tour operators and outfitters
Avoided soil erosion	Agriculture, forestry	Municipal water authorities Recreational fishing guides and outfitters
Economic impacts of project expenditures		
Employment contribution (direct and indirect)	All	Federal and provincial governments Municipalities
Economic output contribution (direct and indirect)	All	Federal and provincial governments Municipalities

Section 2.2 discusses accessible methods for estimating revenue and cost savings from ecosystem services, while Section 2.3 discusses accessible methods for estimating the economic impacts of project expenditures. Figures 1 and 2, below, summarize the steps for producing each type of estimate.

***Figure 1**. Steps for estimating revenue and cost savings from ecosystem services*

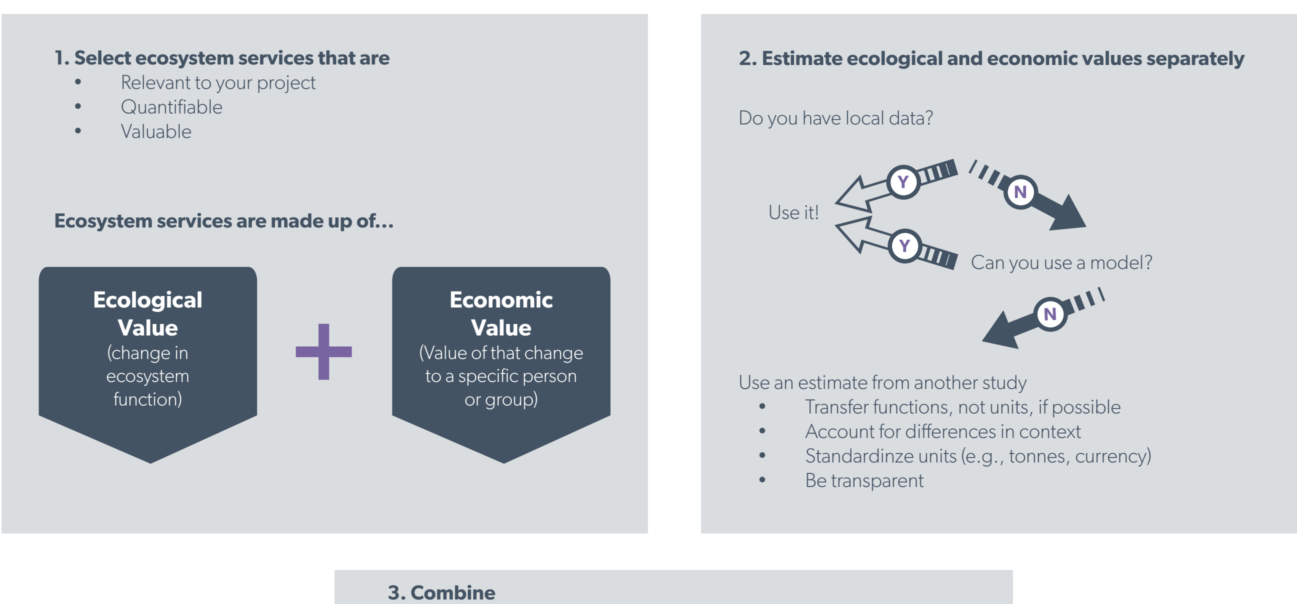
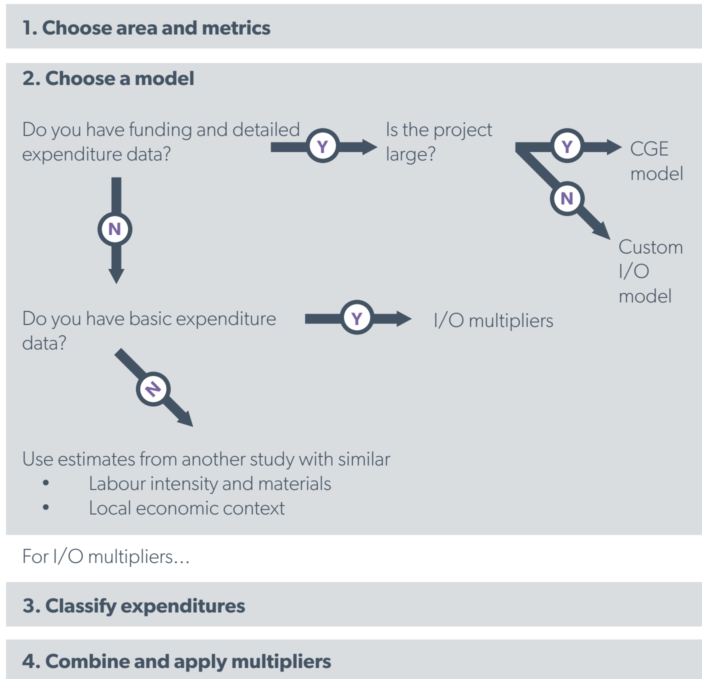


Figure 2. *Steps for estimating economic impacts of project expenditures using input-output (I-O) multipliers*



2.2 Ecosystem service valuation

NBS practitioners can estimate the revenue and cost savings associated with NBS projects using ecosystem service valuation. This term refers to a set of methods developed by environmental economists to estimate the value of a change in "ecosystem services" – that is, ecosystem functions that are directly enjoyed or consumed by humans. While it would be absurd to place an economic value on an ecological function like photosynthesis, which sustains life on earth, ecosystem service valuation methods aim to quantify the ***subjective*** value of a ***change*** in ecosystem service flows to a specific beneficiary (see Box 2). For example, economists have estimated the additional value of the drop in ambient temperature caused by evaporative cooling caused by each additional hectare of urban forest by looking at the reduction in residential air conditioning costs.[20]

The validity of ecosystem service value estimates depends on what they are used for. Estimates of the value of changes in ecosystem services can be used to many ends: to raise awareness and inform the public; to choose between policy alternatives (e.g., to inform land development decisions or identify conservation and restoration priorities), to calibrate the details of a policy once it has been chosen (e.g., to design tax policy), or to facilitate the calculation of damages in court, to name a few examples.[21] The way ecosystem service value estimates are used determines which methods, if any, are appropriate. For some uses, like estimating the value of the ecosystem services that would be lost through degradation of an ecosystem, to inform land use decisions, ecosystem service valuation should be one tool among many, since it cannot capture all aspects of value.[22] On the other hand, ecosystem service value estimates can stand alone when they are only used to represent one type of value for a specific beneficiary – such as estimating an NBS project's potential to reduce built infrastructure costs.

The validity of ecosystem service value estimates depends on what they are used for.

Box 2

Ecosystem service valuation treats value as subjective

Readers may object to calling the cost of air conditioning a subjective measure of value. After all, the price of air conditioning is an objective fact at a given time and place. But prices are a subjective measure of value in that they reflect the subjective attitudes of buyers and sellers: How many other people want something? How would they use it? An objective measure of the value of air conditioning would be based on objective properties of the air conditioning itself, such as how much labour or energy went into producing it.

Most of mainstream environmental economics, including ecosystem service valuation, is based on a subjective theory of value. Rather than attempting to estimate the inherent value of a change in an ecological value, environmental economists estimate the value of that change *to a specific person or group*. This subjective value can be estimated through market prices or by guessing at what prices would be by studying behaviour or using surveys or other tools to understand preferences that cannot be measured through behaviour. The same ecological function may have very different value for different parties: for example, the Municipal Natural Assets Initiative found that 240 metres of a remnant stream in Oakville was worth little to citizens but provided $1.2-1.4 million in storm water management services to the municipality.[23] The subjective theory of value rests on a few contested assumptions about humans' relationship to the natural world – notably, that economic value only comes from human preferences and that all goods and services can be functionally replaced, including those provided by the natural environment. Even so, ecosystem service valuation can be a useful tool for communicating aspects of value to potential funders, as long as it is used appropriately, and its limits are understood.

We identify a three-step process by which NBS practitioners can estimate the revenues or cost savings from changes in ecosystem services:

1. Identify key ecosystem services
2. Estimate the increase in ecosystem services due to the project
3. Estimate the economic value of these changes

The rest of Section 2.2 provides general guidance on each of these steps. In Section 3, we provide more specific guidance for selected ecosystem services, which we then apply to case studies in Section 4.

Identifying ecosystem services

A credible estimate of the value of a change in ecosystem services requires a clear, specific definition of the ecosystem services in question. First, NBS practitioners should adopt one of a few widely used ecosystem service classification systems, to make estimation and communication easier. Second, NBS practitioners should identify a few key ecosystem services that are affected by the project in question, can be easily estimated, and will generate substantial revenues or cost savings for promising prospective funders.

Choose a classification system

The natural world is complex and there is more than one way of dividing it into discrete "ecosystem services". But there are a few best practices for doing so that make it easier to measure changes in service levels and estimate economic value without double counting.[24] Ecosystem services should be:

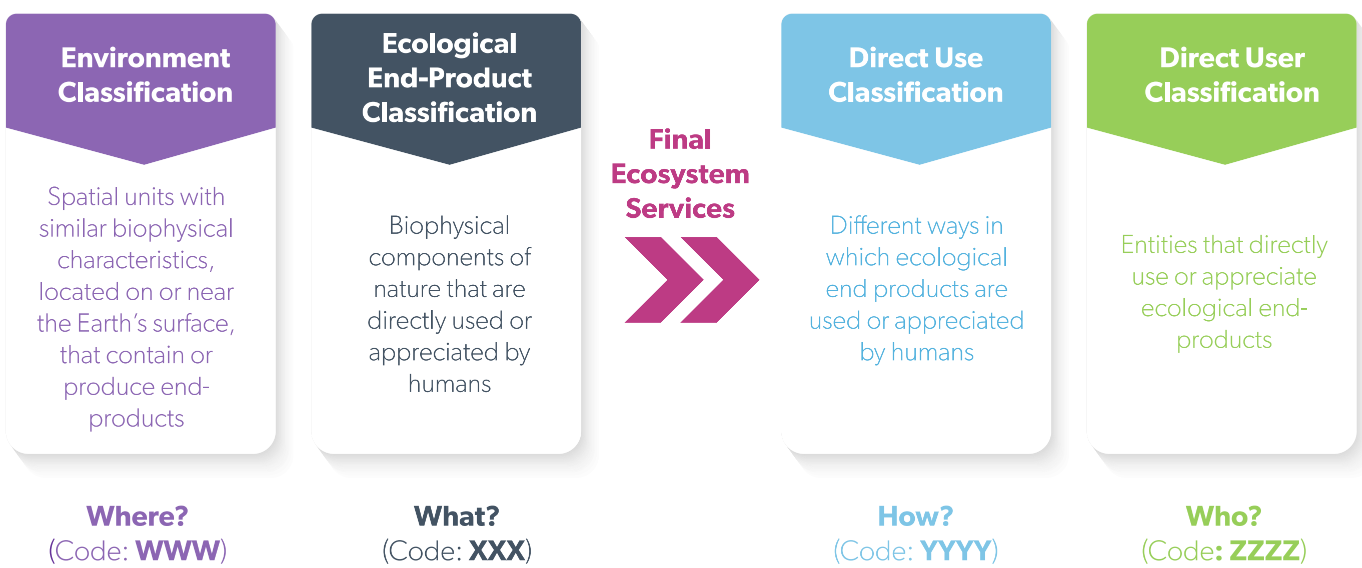
- **Final services**, meaning they are "directly enjoyed, consumed, or used to yield human well-being."[25] For example, the shade provided by forests which lowers stream temperatures is an intermediate service; the fish population sustained by these low temperatures and available to recreational anglers is a final service.
- **Measurable ecological phenomena** rather than functions or processes. For example, instead of "nutrient cycling," NBS practitioners should measure nutrient availability in soil.
- **Benefit-specific and spatially explicit**. For example, if we are interested in quantifying the value of reduced erosion (an ecological parameter) in reducing water treatment costs (an economic one), the ecosystem service of interest is a reduction in concentrations of sediment in water as measured at the treatment plant.[26]

There are a few popular ecosystem service classification frameworks that attempt to realize these principles (see Table 2). Statistics Canada has not yet made a clear commitment to one classification system. In 2013, when Statistics Canada piloted a set of ecosystem accounts, it used the classification system from the United Nations' System of Environmental-Economic Accounting Experimental Ecosystem Accounting manual. However, this project resulted in limited development of statistical infrastructure. As discussed in Table 2, different classification frameworks are popular in different regions and communities. This guidebook adopts the NESCS Plus classification system, due to its focus on identifying specific beneficiaries and its popularity in North America (Figure 3).

Table 2. *Popular ecosystem service classification frameworks*

Classification name	Description
Millennium Ecosystem Assessment (MEA)	The MEA pioneered the practice of distinguishing between provisioning, regulating, supporting and cultural services in 2005. It prioritized comprehensive representation of ecosystem functions over avoiding double counting. It is still a popular reference point in conceptual discussions of ecosystem services, but less often used for the purpose of valuation.
The Economics of Ecosystems and Biodiversity (TEEB)	TEEB is used by databases such as the Ecosystem Services Valuation Database.
The European Environment Agency's Common International Classification of Ecosystem Services (CICES)	CICES is the most widely used classification system in Europe. CICES includes some intermediate ES; there is some overlap between ES categories; and, as in the MEA, CICES includes ES with some human input (like crops), which could lead to double counting with economic accounts.
The UN Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)	The IPBES classification also includes some intermediate ES and there is some overlap between categories, as it prioritizes representation of the variety of human benefits from nature — including as evaluated by traditional knowledge — rather than avoiding double-counting.
National Ecosystem Services Classification System Plus (NESCS Plus)	Recently published by the United States Environmental Protection Agency (EPA), NESCS Plus combines NESCS and the Final Ecosystem Goods and Services Classification System, the two classification systems previously used by the EPA. NESCS Plus emphasizes the identification of ES beneficiaries in a way that harmonizes with economic accounting practices and is designed to include only final ES.

Figure 3. *NESCS Plus classification system (image from Newcomer-Johnson et al (2020))*



Choosing key services

NBS practitioners should focus on estimating the value of changes in ecosystem services that:

- Result from their project
- Result in significant revenue or cost savings for prospective funders
- Are easy to measure with available data

Table 3 highlights a few key ecosystem services that often meet these criteria for NBS projects in Canada. There are integrated tools designed to help NBS practitioners identify relevant, valuable ecosystem services, such as the Protected Areas Benefits Assessment Tool+.[27]

Table 3. *Ecosystem services from NBS that result in revenue or cost savings in Canada and the US. "C" refers to conservation; "R" to restoration; and "IRM" to improved resource management.*

Environment	**Ecosystem service**			**Examples**	**Requirements for rough estimation**	
	Ecological	*Use*	*Beneficiary*		*Data*	*Special skills*
Wetlands	Phosphorus retention Sediment retention Nitrogen retention	Human consumption of water	Municipal water infrastructure planners	Wilson (2008); Olewiler (2004); Widney et al (2018) Olewiler (2004) Wilson (2008); Olewiler (2004); Widney et al (2018)	Removal rates Removal costs	None
All	Biodiversity; Species habitat	Supporting recreation and tourism	Tour operators and outfitters	Barbier (2013); Olewiler (2004); Aziz and van Cappellen (2019)	License or tourism revenue in area*	None (for C and R) Population modelling (for IRM)
Wetlands Grasslands Forests	Water retention	Flood prevention	Public and private property owners Insurance carriers	Olewiler (2004); Moudrak et al (2017); IBC (2018); Aziz and van Cappelen (2019)	Hydrologic and hydraulic data Weather data Property location and value data	Hydrologic and hydraulic modelling
Agriculture Forests Grasslands	Soil retention	Erosion prevention	Farmers Municipal water infrastructure planners	Kulshreshtha and Kort (2009)	Public and basic project data	None
Coastal wetlands	Lessening storm surges	Erosion and flood prevention	Public and private property owners Insurance carriers	Barbier (2013); Narayan et al (2017)	Storm surge data Weather data Property location and value data	Storm surge mod-elling
All	Greenhouse gas uptake**	Climate regulation	-	Olewiler (2004); Aziz and van Cappellen (2019); Gallant et al (2020)	Public and basic project data (for C and R) Detailed project data (for unstandard-ized IRM)	None (for C and R) Dynamic carbon modelling (for unstandardized IRM)
All	Biomass productivity	Human consumption as food, fibre, or fuel	Harvester	Bassi et al (2019)	Public and basic project data (for C and R) Detailed project data (for IRM)	None (for C and R) Timber supply or crop modelling (for IRM)

**For conservation and restoration only*

***Note that Greenhouse gas uptake is an intermediate rather than a "final" ecosystem service, since the concentration of carbon in the atmosphere affects humans through its impact on other ecological end products like temperature and ocean acidity.[28] However, we include it because it is a policy priority and relatively easy to quantify the value of due to the robust literature on the social cost of carbon.*

Ecosystem services are difficult to observe directly. It is usually easier to observe the stock of "ecological end products," as the NESCS Plus classification refers to them, from which ecosystem services flow. For example, it is easier to measure the quantity of sediment in a stream near the intake for a water treatment plant than to observe the interaction between the sediment in the water and the plant's equipment, particularly as it is difficult to disentangle which part of the plant's performance is due to the characteristics of the water versus human-made inputs like machinery. For this reason, ecological end products are typically used as indicators of ecosystem service flows.

To anticipate changes in ecosystem service flows or stocks of ecological end products, NBS practitioners need to represent 1) the way things were before the project (a baseline data set) and 2) the changes associated with the project, through either one-off or periodic tracking (some level of periodic tracking is usually necessary to ensure that ecological objectives are being met).

- This task is **relatively simple for conservation and restoration projects**, where one can quantify the ecosystem services provided by the land area conserved or restored. It is easier to transfer per-hectare values from other studies for this type of project.
- This is **more difficult for projects involving improved management of working landscapes**, such as forestry and agricultural landscapes. Here, NBS practitioners need to establish the relationship between specific management improvements and changes in ecological function. For example, an improved forest management project could be broken down into a change in the width of riparian buffers and a change in the average age of trees, both of which can be linked to changes in ecosystem service provision.

Estimating economic values

Methods

There are a range of methods to estimate the economic value of ecosystem services. The appropriate method and level of accuracy will depend on the service and what the estimate will be used for. For example, estimates for the purpose of raising awareness require less precision than for making land use decisions.

Economic ecosystem service valuation methods can be divided into two main categories: market and non-market. According to mainstream economic theory, the value of an additional unit of an ecosystem service is best measured by the price at which that additional unit can be sold. Where ecosystem services are not directly sold on the market (which is most of the time), economists use other methods to estimate what its price would be if it *were* sold on the market.

- **Market valuation** estimates value based on the observable price of an increase in an ecosystem service or of a proxy good or service.
- **Non-market valuation** estimates value in cases where an ecosystem service has no market price or satisfactory market proxy. Value estimates are based on asking people about their preferences ("stated preference" methods) or examining their behavior ("revealed preference" methods) — for example, by using a hedonic price model to compare home prices in neighborhoods with different levels of air quality, one can estimate the value that homebuyers place on air quality.[29]

NBS practitioners can use market prices to estimate the value of an increase in ecosystem services when the ecosystem service is either:

- **Sold on a market** (for example, water for irrigation)
- **A substitute** for goods and services that are sold on a market (for example, wetlands can substitute for constructed flood management infrastructure)
    - One can make the economic case for investing in an increase in service provision by estimating the cost of replacing that service ("**replacement cost"**) or the cost of the damage that the service could avoid (**"damage cost avoided"** or "**defensive expenditure"**).
    - The substitute must be probable. Cost data does not contain any information about preferences, which are the basis for value according to mainstream economics.
        - In the case of replacement cost methods, the substitute must be functionally equivalent and the least costly alternative. Just because there is an expensive alternative out there to the flood prevention services provided by wetlands, does not mean anyone wants to pay for it. It could be so expensive that a municipality would prefer to pay the cost of flood damage or pay to relocate elsewhere.
        - In the case of the damage cost avoided methods, value should be attributed to changes in ecosystem services based on the amount of avoided costs that would otherwise occur in their absence. For example, the value of a healthy wetland could equate to the avoided expenditures for other types of water quality infrastructure.

- These techniques assume that the benefits are at least as large as avoided costs.[30]

- **A central input** for a good or service that is sold on the market (for example, trout populations are a central input for recreational angling)
  - This approach is difficult to use with rigour because we do not know what proportion of the value of a good or service comes from the ecosystem service. For example, if a conservation project causes an increase in a stream's trout population, it may allow a nearby angling outfitter to sell more angling trips on that river. Angling cannot happen without fish, but the outfitter adds some value through the guide and the provision of gear.[31]

Notes on value transfer

Gathering data from your site will always be more accurate than transferring estimates from other sites. Empirical research has found that transferring ecosystem services values often results in errors.[32] This is because the ecological and economic values used to estimate ecosystem service value both depend on context.

The ecological value of a hectare of land depends on its surroundings

Many studies give a single estimate of the ecosystem services provided by one hectare of a healthy ecosystem. But in reality, two identical hectares would provide different levels of ecosystem services in different contexts. For example, the rate of nutrient retention by wetlands and riparian buffers depends on the rate at which these nutrients enter the wetland, which can be determined by ecosystem characteristics but also by other factors such as surrounding land use.[33] When nutrients enter in concentrated streams, removal rates are much higher. In contrast, when nutrients enter through runoff or through lakes or ponds, removal rates are lower. In this case, per-hectare estimates of ecosystem service provision must account for the size of the site and surrounding land uses.

If you plan to use evidence from a different site to make estimates, transferring a function is better than transferring a unit value. This is because a function contains information about how the value of interest changes as site characteristics or context changes, making it easier to adjust the transferred value to fit your site. This function could come from an individual study, or from a meta-analysis. For example, the following is a simplified representation of the pollution-reducing function of a riparian buffer: $L_W = L_0 e^{-\Phi W}$.[34] In this equation, L is the pollutant load remaining after the water has gone through the buffer; W is the width of the buffer; and Φ_w is the fraction of the pollutant load removed by an additional unit of buffer beyond W. This equation is used by the InVEST tool to model water purification and nutrient retention.

Two identical hectares would provide different levels of ecosystem services in different contexts.

The economic value of a given ecological change depends on people

The economic value of ecosystem services depends on their use by people, and thus on nearby population and economic activity.

Population:

- The more people living nearby, the higher the calculated value of ecosystem services.[35]

- Statistics Canada provides spatial datasets of population distribution in Canada at a resolution of 10 kilometres.[36] In terms of non-spatial tools, Census Mapper can give a rough estimate of population.[37] One global meta-analysis of ecosystem service values for wetlands in agricultural contexts found that population was best measured at a scale of 50 km radius from each study site.

Economic activity:

- The more economic activity nearby, the higher the value of ecosystem services.[38]

- Studies often use "gross cell product," a spatially disaggregated measure of contribution to economic output, to measure economic activity. Yale University's Geographically Based Economic Data (G-Econ) dataset breaks the globe into 1-degree-latitude by 1-degree-longitude squares (roughly 11,100-hectare) and provides data on gross cell product for each square.[39]

Since the economic value of ecosystem services depends on nearby population and economic activity, remote projects will appear less economically valuable for most ecosystem services. This is a limitation of this approach to estimating the value of NBS projects, as remoteness can be an asset for conservation areas,[40] and there is limited overlap in Canada between capacity to provide ecosystem services and consumption of ecosystem services by human populations.[41]

The economic value of a given ecological change also depends on supply

Like any good or service, an ecosystem service tends to have a higher price when it is scarce. This means that, just as ecosystems have diminishing returns to scale in providing ecosystem services, ecosystem services have diminishing returns to scale in generating economic value. Meta-analyses of per-hectare values from ecosystem services have found that they are negatively related to ecosystem size and the number of ecosystems in the area, reflecting the combined effect of these two different types of diminishing returns.[42] This may seem counterintuitive: for example, a large swath of untouched forest has substantially more ecological value than fragmented pieces. But when it comes to air quality provisioning, for example, an individual tree in a city is valued higher (economically) for its contributions than the same tree in a rural setting. There are exceptions for some ecosystem services: for example, the value of carbon sequestration is effectively constant because 1) the need for that ecosystem service is very large and 2) the service is consumed globally.

Supply, demand, the service itself, how important proximity is for delivery, and the underlying ecological value all inform how changes in an ecosystem influence its capacity to deliver valuable ecosystem services.

Should you use value transfer?

While gathering your own data is more accurate, practitioners often need to transfer values because:

- **Value transfer is cheaper and quicker.**
- **Value transfer may be preferable to poor-quality primary research.** For some ecosystem services, estimated values vary more widely among low quality studies.[43]
- **Value transfer is easier for conservation and restoration than for improved resource management.** For the latter, per-hectare values depend on the management changes adopted. Value transfer is only feasible when management changes are standardized. For example, "use of a winter rye cover crop with potatoes" is more standardized than "increased timber rotation age."

Approaches to value transfer

Transferring unit values (after adjusting for income differences or price levels). This works if you can find a similar study site.

Transferring a value function from one study. This also works if you can find a similar study site and is preferable to transferring unit values.

Transferring a value function based on a meta-analysis. Meta-analyses gather data from multiple studies on unit values and site characteristics and estimate an equation for one based on the other. Meta-analyses can be helpful when studies exist with each of the important characteristics of the project site, but not in the right combination.

Best practices for value transfer

Transfer functions, rather than unit values, if possible. This lets you adjust for contextual factors more easily.[44]

Account for differences between sites and studies. If you do transfer a unit value, adjust it based on:

- Socio-economic context (population wealth, density).
- Physical/environmental characteristics (availability of substitute services).
- Time period (always account for inflation and different currencies when transferring monetary values; values may also change over time for reasons other than inflation, like changes in preferences or local economies). All of the transferred monetary values in the case studies below have been converted to 2021 Canadian dollars.
- Measurement units. For example, check that weight units are consistent and that greenhouse gas amounts are expressed in the same units with the same approach to adjusting for warming potential.

Check for errors. Do the ecological and economic values, and the methods used to produce them, seem plausible? Practitioners' instincts can be a valuable check on academic assumptions.

Be transparent. Transferred values need to be treated with caution. By including details on where data were acquired and how they were analyzed, you allow others to better evaluate the credibility of values. This prevents the propagation of misunderstandings and will make your estimates more credible to readers.

2.3 Economic impact of project activities

Implementing NBS projects requires labour, materials, and equipment. When NBS practitioners purchase these, they impact economic indicators such as jobs and economic output both directly (by employing people and buying goods or services) and indirectly (by buying goods and services which themselves require labour, materials, and equipment to make). Finally, they "induce" further jobs and output contributions when employees spend their wages. Economic impact analyses often include induced impacts, but the methodology for estimating these is more complex and rests on assumptions that are not always appropriate.[45] In the interest of conservatism and simplicity, we leave induced impacts out.

Employment and output are the economic impact metrics most commonly assessed by public and philanthropic investors, although they are still rarely estimated in funding proposals for NBS projects. There are also other economic impact metrics which one could assess, outlined in Table 4.

Table 4. *Common metrics for economic impact.*

Metric	Description
Jobs	Statistics Canada's multipliers use total jobs created, whether full- or part-time. Other sources often use full-time-equivalents, where part-time work is counted as a portion of full-time work according to the number of hours worked.
Output	The total value of goods and services whose production is paid for by project expenditures. This measure potentially double-counts goods or services that are inputs for other goods or services.
GDP	The total value added of goods and services whose production is paid for by project expenditures.
Labour income	Includes wages, salaries, payroll benefits, and sole proprietor income.

NBS practitioners with limited resources can make a reasonable rough estimate [of economic impacts] using basic project expenditure data and publicly available Canadian I-O models.

Direct economic impact is determined by the labour, materials, and equipment purchased by the project organizer. A project's direct impact on jobs can be estimated by the staff working on the project, on output, by total project expenditures.

Indirect economic impact is determined by the labour, materials, and equipment purchased by the suppliers of goods and services purchased by the project to produce those goods and services. To estimate indirect impacts, data on how money moves through the economy is needed. Statistics Canada collects this data in its supply and use tables and presents it in an easy-to-use format through its input-output multipliers.[46]

Estimating economic impacts

Choose a model

To determine the impact of a project on local jobs or economic output, we need a model. We cannot measure impact directly because we do not have data on every transaction in the economy.

Estimates of the economic impacts of NBS projects are typically based on input-output (I-O) models. I-O models organize information about how money spent on each economic sector is typically re-spent in a given region. Among other things, they allow calculation of direct and indirect multipliers for jobs and output for a given sector and region. For example, the indirect jobs multiplier for the forestry sector in Ontario tells you how many jobs are created, on average, per million dollars of expenditure in that sector. I-O models rely on assumptions, which we discuss in Box 3.

Box 3

Simple input/output models make simplifying assumptions

Simple I-O models make assumptions that simplify reality. They calculate a fixed "recipe" for how each economic sector combines inputs to make outputs, and they assume that the prices of these inputs do not change. This ignores the fact that a large facility may use less inputs or obtain inputs at lower prices, and that if one sector uses more of an input, it may raise that input's price, affecting all of the sectors that use it.

In contrast, a dynamic model such as a computable general equilibrium (CGE) model allows more flexibility. A CGE model accounts for how changes in demand for inputs can change input prices and thus change input usage patterns. CGE models also account for the fact that sectors are competing for finite labour, land, and capital, meaning growth in one sector could reduce their availability to other sectors in the short term.

These limitations of simple I-O models do affect the result of economic impact analyses.[47] But these impacts will be most important for large NBS projects that use regionally significant quantities of materials, labour, capital or land. Academic studies often combine I-O models with dynamic models that do a better job of capturing these complexities.

If you have the resources, detailed data, and expertise to do so, using a customized, proprietary I-O model like IMPLAN[48] or embedding your I-O model in a dynamic model such as a computable general equilibrium model[49] can give a more accurate estimate of economic impacts. Customized models also allow estimation of local impacts, while Canadian public

I-O models only provide information on provincial and national impacts. But NBS practitioners with limited resources can make a reasonable rough estimate using basic project expenditure data and publicly available Canadian I-O models.

The rest of this section lays out the approach for making this "rough estimate" and discusses the assumptions it relies on. The steps are as follows:

1. Define the area and timeline
2. Categorize expenditures
3. Apply multipliers

Define the area and timeline

Area: Decide whether you want to estimate impacts locally, provincially, or nationally. Examining a larger area will reveal a bigger impact, because even projects that focus on local procurement require some inputs from outside the region or province. Ideally, NBS practitioners would identify local, provincial, and national impacts, but local data can be difficult to find. As mentioned earlier, Statistics Canada only provides I-O multipliers for provincial and national-level impacts. In Appendix B, "all provinces" multipliers are for impacts across all provinces, while "within province" multipliers are for impacts within the province. The former is better for demonstrating the magnitude of impacts, while the latter is better for demonstrating the potential to generate in-province benefits.

Timeframe: I-O models provide static, short-term impact estimates. This means the timeframe chosen should not be too long: if a static model is used to estimate the impacts of expenditures made over 10 years, the results will be inaccurate. I-O models are usually used to estimate the impact of one-time expenditures at the start of a project, such as construction, but they can also be used to estimate the impact of recurring expenditures if expenditures are aggregated over a relatively short period of time (e.g., yearly operations and maintenance costs). I-O multipliers capture the structure of the economy at a point in time, and they are periodically updated by Statistics Canada. If NBS practitioners are calculating the impact of yearly expenditures in the past, they should use the multiplier closest to the year in which the expenditures were made.

Categorize expenditures

Assign expenditures to the categories used by the I-O multipliers. Statistics Canada's multipliers use the Input-Output Industry Classification (IOIC) system to categorize sectors of economic activity.[50] Expenditures should be assigned to the industry that directly produces the goods or services purchased (e.g., a purchase of farm machinery should be assigned to farm merchant retailers rather than farm machinery manufacturing). Expenditures on in-house staff time should be assigned to the category that best corresponds to your organisation's activities. Appendix B lists job and economic output multipliers for common areas of expenditure for NBS projects.

Apply multipliers

Apply multipliers to expenditures in their respective sectoral categories by multiplying them together. This means that NBS projects will have overall multipliers that constitute a weighted average of the multipliers for all of its expenditure categories, weighted by the amount spent on each.

This method is simple and cheap, but also crude. The categories of economic activity for which Statistics Canada provides multipliers are, unfortunately, broad and do not align neatly with NBS project activities. For example, management consulting is in the same category as environmental consulting, although these types of economic activity likely have different spending patterns.

Transferring economic impact estimates

If you have detailed expenditure data, it is better to generate a crude economic impact estimate using the method above, than to transfer a high-quality estimate from another region or type of project. This is because I-O multipliers are based on the spending pattern of a specific economic activity and the economic structure in a specific area.

If you do not have access to detailed expenditure data, keep the following in mind when transferring economic impact estimates:

- **Be aware of the study's approach and data sources.** Studies that estimate economic impacts often use estimates from other regions.[51] Rather than transferring an already-transferred value, go to the source.
- **Check whether the same types of impacts are included.** If induced impacts are included, for example, account for this in interpreting your results.
- **Use estimates from the same type of economic activity, or an economic activity with similar inputs.** Multipliers vary widely between activities: for example, within coastal restoration, Edwards et al[52] estimate an average of 33 job-years per million dollars spent on invasive species removal and of 17 job-years per million dollars for oyster reef restoration.
- **Ecosystem similarity is less important than economic similarity.** Tables 5 and 6 show how widely multipliers can vary between Canada and the US and between Canadian provinces. That said, since Canadian studies are sparse, NBS practitioners may face the choice between using evidence from ecologically similar areas of the US, or from ecologically distant parts of Canada. Direct job creation is likely to be similar between the US and Canada. But total jobs or output impact may differ, because different inputs are available in the US and Canada. For example, Canada may purchase inputs from the US which US industries use domestically.

Use estimates from the same size of region. National-level multipliers tend to be larger than regional ones because they include more indirect effects. You cannot use national multipliers to tell you about local effects: the structure of industry and spending habits are different at the local level.

Table 5. *Job multipliers per $1 million spent on the "Support activities for agriculture and forestry" sector.*[53]

Country	Direct	Indirect	Induced
Canada	7.65	2.79	2.81
US	5.09	4.06	2.61

Table 6. *Jobs multipliers per $1 million spent on the "Other engineering construction" sector.*[54]

Province/territory	Direct	Indirect	Induced
Ontario	4.97	2.85	2.22
Northwest Territories	1.74	0.77	0.33
British Columbia	3.54	3.21	1.90

3. METHODS FOR ESTIMATING SELECTED ECOSYSTEM SERVICE VALUES

This section contains more detailed methods that can be used to estimate the value of four selected ecosystem services. These four ecosystem services were selected because they are often affected by NBS projects, tend to create revenue streams and cost savings for parties who could potentially fund NBS projects, and can be estimated – roughly – using publicly available data, methods, and tools that are accessible to non-experts. In Section 4, we apply the methods discussed in this section to our case studies.

The four ecosystem services are:

- Greenhouse gas uptake
- Phosphorus removal from water
- Recreational fishing
- Reduced soil erosion

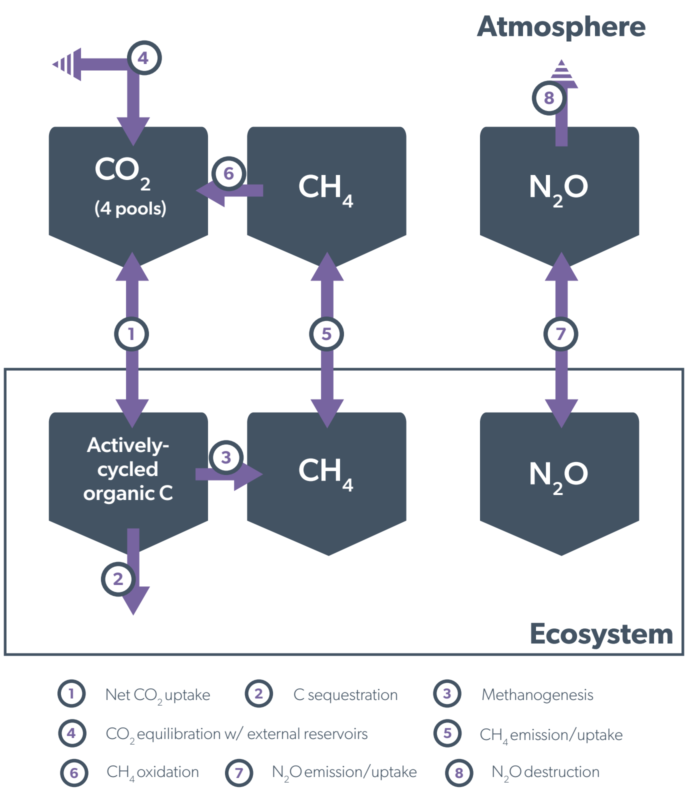
3.1 Greenhouse gas uptake

Ecological value

Which greenhouse gases matter?

The most important GHGs emitted and sequestered by biological systems are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Figure 4 contains a simplified diagram illustrating the movement of these GHGs between ecosystems and the atmosphere.

Figure 4. *Simplified model of GHG fluxes in ecosystems. Source: Neubauer and Megonigal (2015).*



For some ecosystems, fluxes of CH_4 and N_2O have an important impact on overall warming potential. Globally, ecosystems are a net source of N_2O, but under certain conditions, including in low-nutrient environments, ecosystems can be net sinks. As for CH_4, wetlands are usually sources, while forests, agricultural lands, and grasslands tend to be net sinks.[55] Wetlands typically have a net warming effect due to CH_4 emissions at the start of their life, which becomes a cooling effect over time.[56] This means that for wetland restoration projects, the time frame used to assess warming or cooling potential will be very important in determining the result.

On units

CO_2, N_2O, and CH_4 each have different impacts on global warming. This is because they have different atmospheric lifetimes (they stay in the atmosphere for different lengths of time) and different radiative efficiencies (they absorb and re-radiate different amounts of infrared radiation while in the atmosphere). To estimate the net warming or cooling effect of combined fluxes of different GHGs, it is common practice to express fluxes of N_2O and CH_4 in CO_2 equivalent (CO_2e) units by adjusting mass to account for each GHG's radiative efficiency and atmospheric lifetimes. One tonne CO_2e of a greenhouse gas absorbs the same amount of energy in the atmosphere as one tonne of CO_2 over a set period, usually 100 years.

When transferring estimates of GHG flux from other studies, be sure to check which type of conversion factor is used.

The most common approach to CO_2e conversion is to multiply the mass of the GHG emitted or sequestered by that GHG's "global warming potential" (GWP) for the chosen time period.[57] GWP values reflect the radiative efficiency and atmospheric lifetime of a tonne of a GHG, emitted in a single pulse, over a set time period. If the period is not specified, it is safe to assume that it is 100 years. The GWP approach has been used by the Intergovernmental Panel on Climate Change since its adoption into the Kyoto Protocol in 1997, and has subsequently been widely adopted, including by voluntary and regulatory carbon markets and offset programs.

While the GWP conversion factor is popular, there are more ecologically-accurate approaches to converting to CO_2e that are equally easy to apply. GWP conversion factors assume emissions or uptake occurs in a single pulse, while in reality, biological systems continuously exchange GHGs with the atmosphere.[58] The sustained-flux global warming potential (SGWP) is an alternative type of conversion factor that accounts for this fact. Overall, using GWP conversion factors will usually result in underestimation of the warming (or cooling) effect of sustained emissions (or uptake) of CH_4 and N_2O (see Table 7).

If NBS practitioners prefer to use SGWP conversion factors due to their accuracy, they may want to include GWP-derived estimates as well, since these are the most widely understood among prospective funders. When transferring estimates of GHG flux from other studies, be sure to check which type of conversion factor is used; SGWP conversion factors are more popular in the ecological sciences.[59] In the case studies we explore in this guidebook, all mass units are expressed in tonnes CO_2e using GWP conversion factors, since these are the most widely-used conversion factors among prospective funders.

Table 7. *Comparing conversion factors for greenhouse gases*[60]

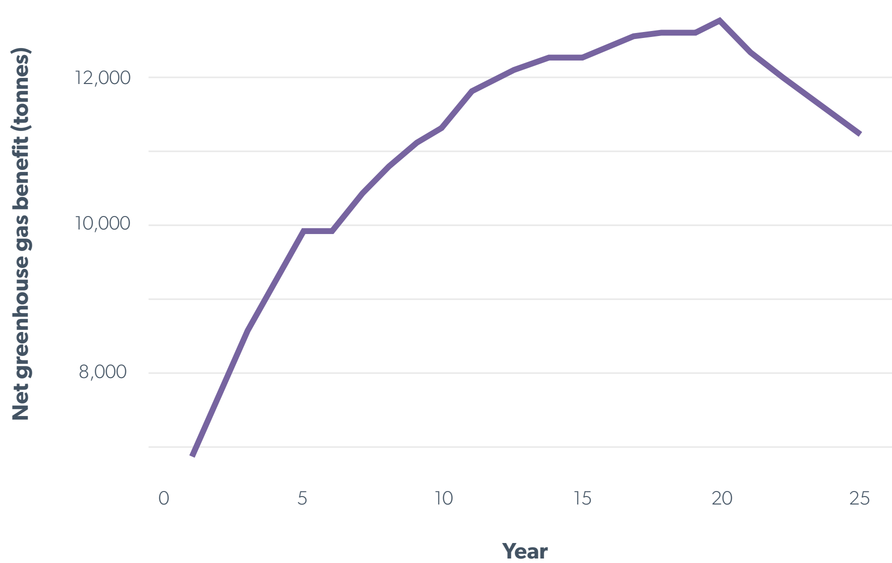
Greenhouse gas	Time period	Global warming potential	Sustained-flux global warming potential
CO_2	Any	1	1
	20	87	96
CH_4	100	32	45
	500	11	14
	20	260	250
N_2O	100	263	270
	500	132	181

Some studies, particularly in the ecological sciences, use tonnes of carbon as the unit when discussing fluxes of CH_4 and CO_2. Tonnes of carbon can be converted into tonnes of CO_2 or CH_4 by adjusting for the molecular weight of carbon relative to the molecule. One tonne of carbon corresponds to 3.67 tonnes of CO_2 and 1.34 tonnes of CH_4.

Dynamic or static estimates?

Dynamic GHG estimates are always preferable to static ones, but they require expertise. They are more important for restoration and improved management projects than for conservation. Plants, soils, geologic formations and oceans remove GHGs from the atmosphere through various chemical and biological processes and store it for different periods of time. The amount of a GHG removed is determined by complex systems and varies over time and across contexts. Ecosystem service valuations simplify this complexity by looking at "net GHG benefit": how a project changes atmospheric GHG levels each year compared to what would otherwise happen. Net GHG benefit will change over the lifetime of a project.[61] For example, Figure 5 shows projected net carbon values over 25 years for an improved forest management project in British Columbia, the Cheakamus Community Forest, which increase in a non-linear fashion.

Figure 5. *Forecast of net greenhouse gas benefit for the Cheakamus Community Forest project (data from Living Carbon Investments et al (2014))*



The most accurate representations of GHG fluxes between ecosystems and the atmosphere will employ dynamic models which combine mathematical rules about the behaviour of natural and social systems with site-specific data. Both voluntary and regulatory carbon offset programs require dynamic modelling to inform offset credit allocation.

While dynamic estimates are best, they are not always necessary. Dynamic estimates require more resources and expertise to produce than static ones. Static estimates can suffice when precision is less important, particularly when the project involves conservation of a stable ecosystem (rather than restoration or changes in management). For example, while the net greenhouse gas flux of wetlands does fluctuate, this mainly occurs either over centuries or between seasons.[62]

Data sources

Fluxes

- Global Forest Watch provides spatial data on both gross carbon removal and net greenhouse gas flux in forests between 2001 and 2020.[63] This data is produced by modeling using data on forest type, ecozone, and forest age. The data has a high spatial resolution (30 metres) and is derived from a model that combines ground, airborne and satellite observations of forest characteristics and changes or disturbances.

- The second State of the Carbon Cycle report is another good resource for identifying static sequestration estimates for different types of ecosystems in different locations.[64]

- The Smithsonian Institute maintains the Global Forest Carbon Database, an open-access database for ground-based measurements of forest ecosystem carbon stocks and annual fluxes from peer-reviewed publications.[65] It does not have data for all areas of Canada, but the data it does have is of high quality.

Stocks

- While the amount of carbon in plant biomass varies, 50% is often used as a default value for living plant biomass.[66] NBS practitioners can use biomass data from the total live aboveground and total dead biomass datasets from 2015 National Forest Inventory, where estimates are provided for each ecozone.[67]

- The National Forest Inventory also provides an online biomass calculator for merchantable and non-merchantable timber stands.[68] Two levels of detail are available:
    - The simple version of the biomass calculator asks for the province, ecozone, and species breakdown by volume.
    - The more detailed version of the biomass calculator requires a CSV file with basic forest inventory data. The biomass calculator website provides some information on what should be in this file but leaves some gaps. To inform practitioners who wish to use the biomass calculator, Table 8 describes each column in the CSV file.

- SoilGrids, an initiative of the International Soil Reference and Information Centre, provides data on soil organic carbon stocks in topsoil (up to 30 cm in depth), with subsoil data in development.[69] The data is modelled using machine learning and input data on local environmental conditions from the World Soil Information Service database. This data has a spatial resolution of 250 metres.

- For wetlands, data on peat depth and carbon content is available for much of Canada in scattered government-commissioned reports, and some provinces publish datasets on wetland attributes. For example, the Ontario Geohub provides a spatial dataset with information on the attributes of Ontario wetlands that can be used to estimate carbon storage.

- WWF-Canada's Carbon Map initiative also provides a spatial dataset of carbon stocks in aboveground and belowground biomass for all of Canada.[70] This data is derived from ground and satellite observations of carbon stocks, climate and topographic data, with a spatial resolution of 250 metres.

Table 8. *Inputs for National Forest Inventory merchantable biomass calculator*

Column	Description	
stand_id	Can be any number that uniquely identifies a stand of timber. A stand number can recur in several rows if the stand has multiple species or multiple layers of canopy.	
province	Use two-letter ISO codes	
ecozone	1 - Arctic Cordillera 2 - Northern Arctic 3 - Southern Arctic 4 - Taiga Plains 5 - Taiga Shield 6 - Boreal Shield 7 - Atlantic Maritime 8 - Mixedwood Plains	9 - Boreal Plains 10 - Prairies 11 - Taiga Cordillera 12 - Boreal Cordillera 13 - Pacific Maritime 14 - Montane Cordillera 15 - Hudson Plains
lead_crit	Quantitative criteria used to rank species occurrence: CA – Crown area VL – Volume BA – Basal area CT – Stem count Null – May apply to vegetated non-treed	
layer_rk	If you have data on multiple canopy layers for each stand, this indicates layer rank in terms of dominance. If you only have data for a single layer for each stand, this can be 1 for all rows.	
vol_total	Total volume per hectare for the entire stand	
vol_merch	Can be blank	
closure	Crown closure, in percent	
genus species	Codes can be found in the data dictionary[71]	
variety	Can be blank	
percent	What percent of the stand is made up of that genus and species, using the criteria identified in lead_crit?	

We need better public data on carbon fluxes and stocks in ecosystems. While a number of non-profit and academic sources provide relatively detailed modelled data, there is a need for more real-world data-gathering to ensure the accuracy of models and account for the large variety of conditions that can affect carbon fluxes and storage. The National Forest Inventory does this, but it is conducted infrequently and focuses on managed forests.[72] There is a need to gather more data on carbon stocks and fluxes in unmanaged forests and non-forest ecosystems, particularly peatlands, which store vast quantities of carbon.[73] As this data is gathered, it should be made publicly available in an open-source format that is accessible to non-expert practitioners.

Transferring GHG estimates

As always, try to choose studies from sites that are similar to the site for which you are trying to produce an estimate. The most important characteristics to match will depend on the project type. For example, for an agricultural NBS project using cover crops (CC), the following are important characteristics[74]:

- **How much biomass the CC adds to the soil**. More biomass input means more soil carbon sequestration.
- **How many years the CC has been used for**. Cover crops increase soil carbon content in the long-term, but it takes a few years for effects to be seen.

- **The level of soil carbon before the CC was implemented**. Low initial levels of soil carbon – for example, in eroded soils – mean a greater ability to absorb and retain soil carbon.

- **Soil type**. More clay content means a better ability to store and retain soil carbon.

- **CC species**. A mix of species increases soil carbon more because more biomass is produced; grass cover crops increase soil carbon more than legume cover crops, because they decompose more slowly.

- **Tillage management** affects the rate of decomposition of plant residue which affects soil carbon.

- **Climate** affects both biomass production and decomposition rate.

Economic value

GHG uptake is not a final ecosystem service, since it mainly affects humans through its impact on other ecosystem services like ambient temperature, flood frequency, or fish populations. But it is still worth estimating its economic value, for a few reasons:

- Markets for carbon now exist, offering the possibility of revenues from GHG uptake
-
- Atmospheric GHG reduction is of great interest to a broad variety of funders and potential funders for NBS projects, even in the absence of revenue streams

- These economic value estimates are fairly straightforward to produce

There are two main approaches to estimating the economic value of GHG uptake:

1) Using the **market price** of carbon offset credits

2) Using estimates of the **social cost of carbon**

The appropriate choice depends on what will be done with the estimates:

- **Offset prices are a better valuation tool if your goal is to indicate potential revenue streams.** This method tends to produce much lower value estimates, since neither regulatory nor voluntary carbon prices are as high as most estimates of the social cost of carbon. However, the value can be entirely captured by a private party.

- **The social cost of carbon is a better valuation tool if your goal is to communicate that a project will improve public welfare.** Values may be larger, since they are intended to represent societal preferences. But they will be based on hypothetical markets instead of actual revenue streams.

Estimation using the market price of carbon offset credits

Carbon offsets can be an important source of revenue from NBS projects. Indeed, revenue from offsets alone is sometimes sufficient to attract investment in NBS projects.[75] To sell offsets, NBS practitioners must hire a third party to conduct a carbon inventory, estimate permanence and leakage, and verify additionality. If offsets are to be sold in a voluntary or regulatory market, they must meet the standards set in the corresponding offset protocol. Rather than describing how to formally assess the net carbon benefit associated with a project, which requires special expertise, this section discusses how to produce rough projections of potential revenue from offset sales. For those interested, many examples of formal assessments of net carbon benefit from Canada are available online.[76]

Is the project eligible for offset credits?

- To sell to **regulatory markets**, you need to follow a government protocol. The federal regulatory market accepts credits from provincial and federal protocols, while provincial markets only accept credits from provincial protocols. Regulatory markets tend to have higher prices and more demand but require longer time commitments and more due diligence.

- To sell to **voluntary markets**, you need to follow a protocol developed by a non-profit registry, or a government protocol in some cases.

Determine offset prices. Data on offset prices and volumes is available for regulatory markets:

- **Quebec.** The International Carbon Action Partnership's Allowance Price Explorer provides information on offset market prices in Quebec. In May 2021, the price was $18.80/tonne.[77]

- **Alberta.** The possibility of paying into a fund to compensate for excess emissions, rather than buyer credits, set an effective price ceiling for credits at $30 per tonne in 2020. Offsets are traded through bilateral agreements, so prices are opaque, but they have historically been well below the maximum price and fluctuated widely in response to policy changes and other factors.[78]

- **British Columbia**. The provincial government reports yearly on the price, volume, and identity of offset purchases by public sector organizations in its Carbon Neutral Government Summary. In 2018, the weighted average price was $11.41 per tonne.[79]

- **Federal Output-Based Pricing System.** The excess emissions charge effectively sets a price ceiling for offset credits. The charge is set to be $50 per tonne for the 2022 compliance period.[80]

For voluntary markets, **Ecosystem Marketplace's Global Carbon Hub** is a helpful resource that provides survey data on offset prices and volumes around the world. Prices for NBS offsets are rising, with an average price of $6.09 per tonne for forestry and land use in 2021.[81]

Estimation using the social cost of carbon

The social cost of carbon (SCC) is an estimate of the economic damage done when one additional tonne of CO_2 is emitted. To estimate the SCC, economists combine estimates of how the climate will respond to an additional tonne of carbon, how changes in climate will affect human wellbeing, and the rate at which society is willing to trade present benefits for future ones.

Governments use SCC estimates to compare the costs and benefits of regulations and investments that impact emissions. Since 2010, Environment and Climate Change Canada has used the SCC in cost-benefit analyses for significant regulatory proposals affecting emissions.

Estimates of the social cost of carbon range widely, from -$15.31 to $2736.67 (CAD) per tonne, with varying assumptions and levels of credibility.[82] The Canadian government has typically used the same SCC estimate used by the US government: it has used a value of $50 per tonne since 2016 but is in the process of updating this value.[83] The recent Regulatory Impact Analysis Statement for the federal Clean Fuel Standard acknowledged that recent updates to the models used to produce the 2016 SCC, as well as other recent academic contributions, produced estimates ranging from $135 to $440 per tonne.[84]

Why do SCC estimates vary? The reasons include:

- **Point in time**: The value of the SCC depends on how much greenhouse gas is already in the atmosphere. As more accumulates, more damage is done by additional units.
- **Discount rate**: Most estimates of the SCC treat future economic damages as less consequential than those that occur in the present by applying a yearly discount rate. Discount rates make a big difference to the size of estimates, since they are compounded over time. Any discount rate implies controversial judgements about our obligations to future generations and the way humans form preferences, among other things.
- **The damages included**: What is included in estimates of the SCC are always being updated as our understanding of the impacts of climate change improves. For example, the US Federal Interagency Working Group on the SCC is working to incorporate ocean acidification and environmental justice considerations into a new estimate.[85] Many important potential damages are left out by the current federal SCC estimates.[86]
- **The treatment of low-probability, high-impact events**: While scientists now know with virtual certainty that humans are driving severe climate change, there is still uncertainty about exactly how bad climate change will be. Different climate models assign different levels of probability to a wide variety of low-probability, worst-case climate change outcomes. Because these outcomes entail such severe damage, the probability assigned to them significantly affects estimates of the SCC.[87]

3.2 Wetland phosphorus removal

Ecological value

To our knowledge, there is no publicly available Canadian data on wetland phosphorus removal rates across the country. Instead, there are a number of studies focusing on different locations in Canada and in the US, from which removal rates can be transferred. However, transferring phosphorus removal rates needs to be done with caution: as Table 9 shows, they vary widely, so it is important to choose studies with similar characteristics to your site.

Table 9. *Total phosphorus retention rates by wetlands, Kg/ha/year*

Wetland type	P source	Kg/ha/year	Source
Constructed	Point (wastewater)	80	DeBusk and Reddy (1987)
Constructed	Point (wastewater)	770	Knight et al (1994)
Constructed	Nonpoint	12.2	Wang and Mitsch (1998)
Natural	Nonpoint	1.73	
Constructed	Nonpoint	11-175	Johannesson et al (2015)
Constructed	Nonpoint	4 - 29	Mitsch and Gosselink (2000)
Restored	Nonpoint	7.2[88]	Page et al (2020)
Constructed/restored	Both point and nonpoint	40-190	Land et al (2016)
Constructed	Nonpoint	8.5	Dunne et al (2015)
Natural	Nonpoint	7	Walton et al (2020)
Natural	Nonpoint	4.6	Widney et al (2018)

Phosphorus removal varies depending on wetland characteristics, the most important of which are in Table 10. The most important determinant of phosphorus removal rates is the "loading rate": the rate at which phosphorus enters the wetland.[89] A higher loading rate means higher removal rates. The loading rate depends on the type of wetland and the water source:

- Loading rates are much higher when the phosphorus comes from a point source (such as removal from wastewater streams) than from a non-point source (such as removal from runoff).
- Riverside natural wetlands have a higher removal rate than lakeside natural wetlands, because of the concentrated flow into them, while constructed wetlands have an even higher removal rate because water tends to sit in them for longer.[90]

Temperature and season are also important determinants of removal rates.[91]

To estimate the phosphorous removal rate, the best practice would be to transfer an equation expressing the phosphorus removal rate as a function of site characteristics, rather than transfer a unit value, using the factors in Table 10. An alternative is to transfer an estimate from a site with similar values of key characteristics.

Table 10. *Data sources for important factors affecting phosphorus removal by wetlands, ranked using multi-criteria analysis.*[92]

Importance rank	Factor	Value associated with highest performance	Data source
1	Surrounding land use	Barren land	Provincial government land use data (e.g., Southern Ontario Land Resource Information System)
2	Soil type and drainage	Well-drained	Provincial government soil surveys
3	Topography	-	Digital elevation model
4	Temperature	Higher temperatures	Meteorological data
5/6	Wetness	-	Digital elevation model
5/6	Slope	High slope	Digital elevation model

The same ecological factors also tend to determine the rate at which wetlands remove other nutrient contaminants, such as nitrogen.

Economic value

The value of water filtration ecosystem services, including for phosphorus, is usually estimated using avoided cost methods.[93] For phosphorus, there is limited public data on removal costs in Canada. And phosphorus removal costs vary widely, both between and within studies: for example, one cost estimate for phosphorus treatment ranges from $10.60 to $329.18 per kilogram.[94]

Most of the available cost data on phosphorus removal comes from point-source wastewater treatment plants, with little available data on the cost of removal from non-point sources like agricultural runoff. Many studies valuing wetland phosphorus removal from agricultural runoff use point-source removal cost estimates.[95] As with many contaminants, removing phosphorus from water grows more expensive as its concentration grows lower. Since wastewater sources tend to have higher concentrations of phosphorus, removal costs tend to be lower. For wetlands that filter phosphorus from agricultural runoff, the replacement costs are likely to be higher.

To estimate phosphorus removal costs from agricultural runoff, we obtained cost estimates from a proposed mechanical treatment facility in York Region, Ontario, which would remove phosphorus from agricultural runoff from Holland Marsh into Lake Simcoe.

A feasibility study by the Lake Simcoe Region Conservation Authority concluded that the proposed facility could remove 2.5 tonnes of total phosphorus per year at an initial capital cost of $40 million and annual operation and maintenance cost of $1.2 million.[96] Assuming a useful life of 50 years and capital interest rate of 3%, in line with average values for the region's capital projects, the project would have the following annualized cost:

$$Capital\ recovery\ factor = \frac{Rate}{1-(1+Rate)^{-Lifetime}} = 0.039$$

$$\begin{aligned} Annualized\ cost & \\ &= (Capital\ recovery\ factor\ x\ Capital\ cost) + Operations\ and\ maintenance\ cost \\ &= (0.039 \times 40{,}000{,}000) + 1{,}200{,}000 = 2{,}760{,}000 \end{aligned}$$

$2,760,000 divided by 2500 kg (the yearly removal capacity) is $1104/kg. This estimate is significantly higher than commonly-used estimates in the literature for removal from agricultural runoff.[97] Several factors may contribute to this finding, including the fact that our cost estimate comes from a plant specifically designed to treat runoff, as well as the fact that some estimates leave out capital costs.[98]

Estimates of the value of nutrient removal are most compelling when they are based on local data, because these indicate a real potential for cost savings. If there are no nutrient removal facilities nearby, NBS practitioners should look for one in a region with similar levels of nutrient pollution from a similar source (point vs. nonpoint) affecting human populations in a similar way (e.g., pollution of drinking water should be treated separately from pollution of recreational beaches). In Canada, the federal Disaster Mitigation and Adaptation Fund often funds water treatment facilities, and their list of funded projects is a good source of information on proposed or funded facilities which may be willing to share real or projected costs.

3.3 Biodiversity for recreational fishing

Ecological value

For **conservation and intensive restoration projects where economic values are available for the area** conserved or restored, no ecological data is necessary to produce a rough estimate of value from recreational fishing. NBS practitioners can assume that recreational fishing would not be possible without the conservation and restoration project and attribute all economic value from recreational fishing activity within the project area to the project. This assumes that all areas of a water body are equally valuable for fish populations, which could lead to overestimating value if fish populations depend on habitat or water quality outside of the area, or underestimating value if fish populations outside the area at the time of fishing depend on habitat or water quality inside the area. This illustrates the challenge associated with breaking complex, interconnected ecological systems into discrete units for the purpose of valuation. This approach should only be used to produce rough estimates.

For **conservation and restoration projects where economic values are not available for the area** conserved or restored, some ecological data is needed to establish how valuable the project site is as a fishing spot compared to the site at which the economic values were calculated. The standard approach is to use fish populations for this purpose, assuming that the value of a recreational fishing trip is proportional to the quantity of fish caught.[99] Habitat suitability indices (HSIs) can also be used as a proxy for the provision of recreational fishing as an ecosystem service.[100] While scattered HSIs are available in Canada, produced by either governments, academics, or proponents undergoing environmental impact assessments, there is to our knowledge no centralized data source like the USDA Forest Service's ArcHSI.

For **improved management projects and restoration projects where the site still supported fish prior to restoration**, dynamic models or detailed data are needed to determine the ecological changes caused by the management improvements and their interaction with fish populations. For example, to estimate the value of erosion reduction measures on a farm for downstream recreational fisheries, one would need to establish the change in sediment deposition in the fishing area and the resulting change in fish populations. Since sediment deposition depends on the watershed, and different species of fish in different habitats have different levels of tolerance for sediment, value transfer should only be done very carefully.[101]

So far, we have focussed on the quantity of fish as our ecological value of interest. In reality, other factors such as scenic beauty, remoteness and tranquillity also affect the economic value of a recreational fishing experience.[102] Since recreational fishing can be a consumer good, it is the only ecosystem service among those we look at where non-market values (like people's preferences) are relevant for determining concrete market values like tourism sector revenues. Studies have used non-market valuation methods such as hedonic price analysis[103] to identify the components of valuable recreational hunting and fishing experiences, but for our purposes, it may make sense to avoid these more complex analyses.

A number of free ecosystem service evaluation tools can map important habitats for biodiversity and even tourism services provided by project sites, using public data. Co$ting Nature and InVEST are two examples.[104] See Appendix B and the Ecosystems Knowledge Network's Tool Assessor for more information.[105]

Economic value

Recreational fishing has different value for different beneficiaries. We focus on revenues from the sale of fishing licenses and from guiding and outfitting services. License sale revenue data is usually published by provincial governments, while guiding and outfitting revenues may be available from tourism associations or on request from local businesses.

It can be difficult to determine what proportion of the value of tourism or recreation is attributable to ecosystem services. Obviously, recreational fishing would not exist without fish. But in the case of a guided fly-fishing tour, the guide and gear also contribute value. Some studies have attempted to isolate the proportion of revenues that are attributable to different parts of the experience using hedonic price analysis.[106] This requires more data and sophisticated methods and may be out of reach for NBS practitioners.

Looking at these revenue streams provides a very conservative estimate of the value of recreational fishing ecosystem services, since fishing license fees are intended to cover administrative costs and shape behaviour rather than capture the value of the experience, only a portion of recreational fishers hire guides or outfitters, and fishing guides and outfitters rely on some public goods. The portion of value captured by market valuation methods will depend on the extent to which the experience is public: fishing on public land uses mostly public goods, while a large portion of the value of a trip to a private fishing club is captured in market prices. Non-market methods such as travel cost methods and contingent valuation can be used to capture other aspects of the value of recreational fishing.[107]

The portion of value captured by market valuation methods will depend on the extent to which the experience is public.

Survey-based data can provide more detailed information on the economic contribution of recreational activities in nature. The 2012 Canadian Nature Survey included questions on individual expenditures including equipment, transportation, food, and accommodation associated with various nature-based activities at a national scale.[108] For recreational fishing, the national annual spending estimate by those who participated was $2.1 billion. These survey findings include average individual expenditures, which for recreational fishing was $469. Applying national data locally includes the same risks of any value transfer but can provide a ballpark estimate in the absence of other data, though as noted in Section 2.2, we recommend carefully reviewing the methods and assumptions of any secondary data source to justify applicability. More regular collection of national data such as those included in the Canadian Nature Survey could substantially improve NBS practitioners' ability to estimate the size of potential revenue sources associated with their projects.

3.4 Soil erosion by water

Ecological value

NBS practitioners should aim to identify the change in erosion in tonnes/hectare/year associated with a change in land management, as these are the units typically used for economic valuation. The change in soil loss due to water erosion associated with a NBS project can be estimated with public data and basic site data using the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC). RUSLEFAC is an adaptation of the Universal Soil Loss Equation (USLE), developed by the US Department of Agriculture in the 1960s, which predicts the long-term average annual rate of erosion on a slope based on rainfall, soil type, topography, vegetation or crop system, and land management practices.[109] The USLE is often used by environmental economists to estimate the economic cost of soil erosion.[110] While RUSLEFAC was developed for agricultural applications and is particularly good for estimating erosion associated with different combinations of crops and agricultural management practices, it can also be used to estimate erosion in forests, pasture, and reclaimed sites.[111]

The RUSLEFAC equation is as follows, with each of the equation's components described in Table 11. This equation tells us that the level of soil loss is determined by the level of rainfall, soil type, slope length and steepness, and what crops and management practices are used on the land.

$$A = R \times K \times L \times S \times C \times P$$

In 2002, Agriculture and Agri-food Canada published a comprehensive handbook on RUSLEFAC that includes factor values for different areas of Canada.[115] The governments of PEI and Ontario have also published more detailed handbooks and factor values for these provinces.[116]

RUSLE2 is an easy-to-use computer model that uses the same basic equation but allows more complex analysis and, in some cases, provides built-in data sources. Compared to RUSLEFAC, it has the following extra features:

- It can estimate erosion rates seasonally and even daily, not just annually
- It can describe management and tillage practices in more detail
- Can handle nonlinear field slope shapes (e.g., concave, convex, s-shaped)

The Government of Ontario has developed an adapted version of RUSLE2 that contains province-specific datasets.[117]

Economic value

Soil erosion can have negative economic impacts both on- and off-site.

On-site, erosion can reduce biomass productivity by causing loss of soil organic matter and nutrients.[118] The economic value of this loss is most commonly estimated using the value of lost crops but is sometimes estimated using the cost of replacing lost nutrients with synthetic fertilizers.

- **The value of lost crops** is difficult to estimate if you cannot find an estimate with the same crop, management system, microclimate, and initial level of erosion as the project site.
    - The processes linking soil erosion and agricultural productivity are complex, and it is difficult to isolate the impact of erosion from other factors.
    - Computer models like the Erosion-Productivity Impact Calculator and the Cropping System Model are typically used to estimate the relationship between soil erosion and productivity, but they tend to be data-intensive and require special expertise to operate. Less data-intensive models have been developed, but to our knowledge, none are accessible to non-experts.[119]

Table 11. *Components of the Universal Soil Loss Equation*

Component	Name	Description
A	Output	Potential, long-term average annual soil loss in tonnes per hectare per year.
R	Rainfall factor	A measure of total annual rainfall and how it is distributed throughout the year. It is measured in MJ mm ha-1 h-1. Pre-computed value based on location.[112]
K	Soil erodibility factor	A measure of soil's susceptibility to erosion, based on soil type. and organic matter content. Measured in t h MJ-1 mm-1. Pre-computed value based on location.
L	Slope length factor	Formula given, with the length of the longest slope as input. Data can be obtained from the Canadian National Soil Database.[113]
S	Slope steepness factor	Formula given, with the grade of the longest slope as input. Data can be obtained from the Canadian National Soil Database.
C	Cropping management factor	Which crops make up the rotation? Choose from given options. Can be based on project data or on data from the Census of Agriculture.[114]
P	Supporting practices factor	A measure of the use of management practices to minimize erosion, like cross slope cultivation and strip cropping. Choose from given options.

- Value transfer should only be used for studies from a similar crop, management system, microclimate, and initial level of erosion, because productivity impacts depend heavily on these factors. This may be difficult as there are only a handful of studies done in Canada that allow per-hectare-per-tonne estimates.[120] It is important to note that older studies may no longer be relevant if topsoil conditions have changed substantially.

- **The cost of replacing nutrients** is less complex to estimate, although it is also a less complete measure of economic value.

    - This is also only accessible to non-experts if they can find a study matching the project context that estimates the change in nutrient runoff associated with a change in soil erosion. NBS practitioners can then use the market price of synthetic sources of the lost nutrients to estimate replacement costs.

Off-site, eroded sediment carried by water can degrade ecosystems, contaminate drinking water, and hamper navigation, stormwater management, and recreation. The value of avoided erosion off-site can be estimated by looking at losses in recreational fishing[121] or at the cost of dredging drainage ditches and waterways[122] and filtering sediment from drinking water. For all of these, it is best to get a local estimate, since the amount of sediment deposited downstream as a result of one tonne of eroded soil depends on settlement delivery rates, which vary between watersheds.

4. CASE STUDIES

Each of the following case studies examines a real conservation, restoration or improved resource management project that has been implemented in Canada. The four case studies represent different landscapes and are intended to highlight the variety of ecosystem benefits that can be calculated using simple methods and public data or basic site data, using the methodological guidelines in the previous sections. Each of the four projects was primarily motivated by ecological or social considerations, rather than economic ones. The economic analysis below is intended to supplement these ecological and social arguments for NBS and potentially expand the range of funders who are interested in supporting these types of projects. We also discuss areas where improved public data could make this type of economic analysis easier.

4.1 Closson Road wetland restoration

Location: Prince Edward County, Ontario

Size: 34.9 hectares

Ducks Unlimited Canada (DUC) restored the Closson Road wetland in 2016. It had been flooded by beaver dams which caused periodic flooding on neighbouring agricultural properties. At the request of the neighbours, DUC replaced the beaver dams with beaver bafflers which allowed control over the water level. At the time of restoration, the wetland was in poor condition due to fluctuating water levels and other disturbances and required restoration. The site is 26% marsh (cattail and reed canarygrass) and 74% swamp (willow thicket and deciduous) and has deep humeric organic soils.



Prince Edward County restoration project. Source: Sean Rootham, Ducks Unlimited Canada.

Ecosystem services

Greenhouse gas uptake

To estimate how much carbon this site stores, we can transfer estimates of the depth and organic carbon density of peat in the Kingston-Belleville area and across Southeastern Ontario, which are derived from field samples (see Table 12).

Table 12. *Average peat depth (for Kingston-Belleville area) and average organic carbon density (for Southeastern Ontario)*[123]

Peat type	Depth (m)	Organic carbon density (kg/m^3)
Deciduous swamp	1.5	72.5
Thicket swamp	1.8	79.7
Marsh	1.0	94.5

If we assume half of the swamp area is "thicket swamp" and half "deciduous swamp," we can estimate average peat depth and average organic carbon density by taking a weighted average of the values in Table 11. We can calculate the total soil carbon stock as follows:

Total carbon stock = Average peat depth x Site size x Average organic carbon density

$$\begin{aligned} \mathit{Total\ carbon\ stock} &= ((0.26 \times 1) + (0.37 \times 1.5) + (0.37 \times 1.8)) \times 349{,}000 \times ((0.26 \times 94.5) \\ &+ (0.37 \times 72.5) + 0.37 \times 79.7)) \end{aligned}$$

This gives an estimate of 41,919.34 tonnes of carbon, or **153.8 kilotonnes**

This estimate using value transfer is significantly larger than an estimate using data from SoilGrids. According to the SoilGrids data, there is a mean value of 63.8 tonnes per hectare of organic carbon stock in this wetland, or 234.2 tonnes per hectare. This translates to 8171.7 tonnes for the whole site. The discrepancy may be explained by the fact that SoilGrids data is only for up to 30 cm in depth.

A study of a temperate marsh in Southeastern Ontario found annual net CO_2 emissions of -8.22 tonnes/hectare, which translates to **-286.9 tonnes** across this property.[124] However, this study also found annual CH_4 emissions of 42.3 tonnes/hectare, or **1476.3 tonnes** each year across the Closson Road wetland. So, while the wetland examined in the study is a net carbon sink, it is a source of greenhouse gases on the 100-year timescale. Whether CH_4 emissions or the removal of atmospheric CO_2 through carbon sequestration are more dominant in wetlands, from a climate change perspective, depends on the age of the wetland and the quantity of live vegetation, among other factors.[125]

This project is not an ideal candidate for the sale of carbon offsets, so it may not make sense to use offset prices to estimate the economic value of GHG uptake. Any offsets produced would need to be sold in the voluntary market as there is currently no regulatory market for offsets from wetland restoration and conservation in Canada. Further, the project is likely not eligible for offsets, as written evidence is required that the wetland would have been destroyed without the project, that there was a financial barrier to maintaining it, and that offsets were seen as removing this barrier. In this case, four landowners were willing to maintain the wetland so long as it did not damage surrounding farmland and signed a conservation agreement with DUC. Under many offset protocols, a pre-existing conservation easement precludes the sale of offsets.

In 2019, the global average price for forestry and land use credits in voluntary markets was \$4.95 per tonne.[126] At this price, this site could yield \$761,310.00 in offsets for storage alone. It could yield \$1420.16 for carbon sequestration if it were not for CH_4 emissions, which seem to negate yearly carbon sequestration on the 100-year timescale. However, even if this site were eligible to generate offsets, it is small, and the potential revenue may not warrant the transaction costs associated with verifying offset credits and negotiating their sale. Services and policies allowing many small sites to sell their offset credits as a package, including ones currently being contemplated for the federal offset program, could change this.

Using estimates of the social cost of carbon seems like a more appropriate way to estimate the economic value of GHG uptake at this site the \$135 to \$440 per tonne range provided in the recent federal Regulatory Impact Analysis Statement for the Clean Fuel Standard,[127] we can **estimate the value of the stock of carbon stored at \$20,768,937.00 to \$67,691,350.23**.

Phosphorus removal

Prince Edward County is an agricultural area and surrounding water bodies have been harmed by the runoff of phosphorus from fertilizer and other sources.[128] Wetlands can effectively remove phosphorus from agricultural runoff,[129] meaning that this site likely provides valuable filtration services.

There is no data on nutrient filtration at this site, so we will need to transfer estimates from other sites. We have two options:

1. Transfer separate estimates of how much phosphorus is removed by similar wetlands and how valuable this removal is, and combine them

2. Obtain a combined estimate of the per-hectare value of phosphorus removal by wetlands

Estimates of phosphorus removal by wetlands vary widely. This is partly due to the varying rigour of study designs, but also the fact that removal rates depend on wetland characteristics. Lower-quality studies tend to find higher removal rates. The removal rate depends on the loading rate, as well as other factors.[130]

What is a reasonable per-hectare removal rate estimate for this site?

- A meta-analysis of high-quality studies of phosphorus removal rates by wetlands around the world identified a mean removal rate of 40 kilograms/hectare/year.[131]

- Estimates from agricultural contexts in Manitoba suggest wetland phosphorus removal rates of between 80 kg/hectare/year to 770 kg/hectare/year.[132]

- In a study of small wetlands in agricultural areas in Ontario, DUC found a mean removal rate of 7.2 kg/hectare/year.

The value of nutrient removal by this site likely accrues in many ways, including impacts on tourism and property values. One direct, concrete aspect of its value is in cost savings for municipal water treatment. To estimate this, we use the avoided cost approach with the $1104/kg cost estimates from the proposed plan at Holland Marsh (see Section 3). The avoided cost approach is common when valuing nutrient removal by wetlands.[133]

This translates into a per-hectare value of $44,160/hectare/year, or **$1,541,184 each year**.

Combined estimate

Through a global meta-analysis, Brander et al[134] came up with the following equation for estimating the per-hectare value of nutrient removal by wetlands in agricultural contexts as a function of site characteristics:

$$\begin{aligned}\ln \mathit{Value\ per\ hectare} &= 3.74 + 0.45(\mathit{Constructed}) - 1.3(\mathit{Water\ supply}) - 0.8(\mathit{Water\ quality}) \\ &- 0.37(\ln \mathit{Area}) \\ &- 0.3(\ln \mathit{Abundance\ nearby}) \\ &+ 0.45(\ln \mathit{Population}) + 0.27(\ln \mathit{Gross\ cell\ product})\end{aligned}$$

Importantly, this equation incorporates non-concrete measures of value, such as contingent valuation, and combines values for removal of other nutrients, notably nitrogen. This means that its output cannot be directly compared to avoided removal cost estimates for phosphorus alone.

We used the following values:

- Area = 34.9 ha
- Population within 50 km radius = ~157,057
- Gross cell product = 0.012 (2005 USD, purchasing power parity exchange rates)
- Nearby peatlands:
    - The Kingston-Belleville area surveyed by Riley[135] is 12,000 km^2. It has 59.22 km^2 of wetlands, meaning wetlands make up 0.005% of its area.
    - In a 50 km radius, roughly half is land. This means there is roughly 3926.5 km^2 of land area within the radius.
    - 0.005% of this area is 19.38 km^2 of wetlands in a 50 km radius.

This produced an estimate of $18,373.39 / hectare / year, or **$641,231.31 each year**.

Discussion

This property is small, but it generates enormous value through **carbon storage ($20.8 million to $67.7 million) and phosphorus removal (~$640,000.00 to $1.5 million per year)**. Further, some of this value takes the form of revenue streams or cost savings, potentially generating interest from new types of funders. In particular, the phosphorus removal benefits of this type of project should be taken into account by municipalities and conservation authorities planning construction and maintenance of water treatment facilities. The value of atmospheric GHG reduction at this site cannot be translated into revenue from the sale of offsets, both because of the specific history of this site and because of its small size. The latter factor will hopefully become less of a constraint as regulatory and voluntary offset programs develop more sophisticated mechanisms for aggregating projects, something which the proposed federal offset regulations provide for. Avoided wetland destruction is currently only eligible for offsets under voluntary protocols in Canada, because of the difficulty of establishing whether avoided emissions would really have occurred.

Greenhouse gas uptake and phosphorous removal are among the easiest to quantify of the many ecosystem services provided by wetlands, which is why we focus on them in this case study. Wetlands remove other pollutants such as nitrogen and sediment, reduce the risk of flooding, and provide key habitat, to name just a few examples.

- **The value of filtration of nitrogen and sediments** could be quantified using similar methods to the ones used here for phosphorus, although there is a lack of public data on the cost of removing these pollutants in different parts of Canada.
- **The value of water level regulation, particularly for flood prevention**, can be quantified using publicly available data but requires the use of dynamic hydrologic and hydraulic models. A public informational tool for NBS practitioners without modelling skills that identified the risk of flooding in different areas, using a severity classification system that accords with flood damage databases such as the Alberta Provincial Flood Damage Assessment Study, would be helpful. The Insurance Bureau of Canada has extensive data on the cost of flood damage which could be made public in some processed form. Flood mitigation is a very valuable ecosystem service performed by wetlands, particularly as climate change worsens.[136] Further, this value takes the form of concrete cost savings for all levels of government and the insurance industry, meaning these parties could be funders for wetland restoration projects.

Table 13. *Overall impact on jobs (total) and economic output (millions of dollars) across Canada from expenditures on the Closson Road wetland restoration (see Appendix B for multipliers)*

Sector	Expenditure	Indirect output impact	Direct jobs impact	Indirect jobs impact
Building material and garden equipment and supplies dealers	$24,750.00	0.01	0.39	0.07
Printing and related support activities	$300.00	0.00	0.00	0.00
Other engineering construction	$78,317.50	0.05	0.32	0.25
Grant-making, civic, and professional and similar organizations	$41,024.55	0.03	0.41	0.16
Other provincial and territorial government services	$33,402.00	0.03	0.09	0.20
Total	**$199,201.09**	**0.12**	**1.21**	**0.69**

Finally, while there is a wealth of evidence on the **importance of wetlands for biodiversity**, this value is difficult to translate into concrete economic value. Better data on changes in nature-dependant tourism and recreation expenditures resulting from conservation or restoration activities could provide a means to estimate a small portion of this value. While the 2012 Canadian Nature Survey provides sampled data on average yearly expenditures on nature-related recreational activities, it does not provide a means to link changes in environmental quality to changes in expenditures. This data does, however, suggest that activities like birding and waterfowl hunting could be significant sources of value for wetland restoration and conservation.

Economic impacts

Project expenditures generated $120,000 in indirect output and 1.9 jobs, according to our estimate (see Table 13). We obtained the estimates in Table 13 by classifying expenditure data from the NBS practitioners in charge of the project into the sector categories used by Statistics Canada and multiplying sectoral expenditures by the "all provinces" multipliers for each sector (see Appendix B).

Discussion

Restoration projects are perhaps the most straightforward type of project for which to estimate impacts on jobs and economic output. It is easy to determine which expenditures are associated with the project, and there are substantial expenditures associated with restoration activities that usually translate into many jobs due to the labour-intensive nature of the work. However, these projects tend to create short bursts of economic activity and employment. This small project generated 1.9 jobs, largely for local contractors, from one-time expenditures during planning and construction. DUC has set aside roughly $20,000 for unspecified future costs associated with upkeep, but these are expected to be small compared to initial expenditures.

4.2 Mount Broadwood Conservation Area

Location: Near Fernie, BC

Size: 8,957.61 hectares

The **Mount Broadwood Conservation Area** (MBCA) was donated to The Nature Conservancy of Canada (NCC) by Shell in 1992. It is connected to the Elk Valley Conservation Area and is close to other Rocky Mountain conservation areas, offering valuable corridors for wildlife. Before the property was donated, some of the forestry rights were sold, so logging by Canfor is allowed up to a cap of 800,000 m^3 of timber over 10 years.

Ecosystem services

Recreational fishing

The site is home to native populations of cutthroat and bull trout, both of which are listed as species of "special concern" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in this region.[137] MBCA provides valuable, high-quality habitat for these populations, which are endangered by habitat loss – driven by forestry, hydroelectric development, mining, urbanization, and agriculture – as well as invasive species and climate change.

Bull trout and cutthroat trout are the two main species fished by anglers in the Elk and Wigwam Rivers.[138] Data on the value of angling licenses in these rivers is available from the BC government,[139] and can thus give us a partial estimate of the value of this protected area in supporting recreational fishing. Angling licenses are sold for the entire length of the Elk and Wigwam rivers.[140]

MBCA borders the Elk River for 8 km and the Wigwam River for 7 km. These rivers have 180 km and 28 km of fishable length, respectively.[141] We calculated the proportion of fishable waters contained within MBCA for each river and used this proportion to determine the portion of the value of fishing licenses sold on these rivers that is attributable to MBCA. In doing so, we assumed that this habitat would be destroyed by an alternative use.

From 2010 to 2019, an average of $403 and $223 were made each year from the sale of licenses along MBCA portions of the Elk and Wigwam Rivers, respectively. Since angling licenses are not priced to cover the entire market value of recreational

Photo credit: Kara Tersen and Nature Conservancy of Canada angling, these numbers should be understood as an extreme lower bound on the value of habitat provision for recreational angling at MBCA.

To estimate economic value from private revenue streams, we spoke with an outfitter who operates a fishing lodge at the edge of MBCA and runs angling tours into the Conservation Area, based on an agreement with NCC. They have the right to run 28 person-days of guided fishing trips on the Elk and Wigwam Rivers within MBCA, and they charge $425 per person-day. This suggests roughly $11,900 each year in revenue from guiding trips within MBCA for this outfitter.

The numbers above are for one outfitter; how much revenue in total could be earned in the area from guiding angling tours? The 2015 Kootenay Area Management Plan recommends 1969 and 120 Guided Angler Days per year on the Elk and Wigwam Rivers, respectively.[142] If we assume guides use all fishable areas on the rivers equally, we can scale these numbers by the proportion of fishable length contained within MBCA, which gives 88 and 30 Guided Angler Days in the Conservation Area on each river, respectively. This means the outfitter we spoke with holds about one quarter of the Guided Angler Days in MBCA, suggesting potential revenue of **$47,600 each year**.

Greenhouse gas uptake

Sequestration: This site has a net greenhouse gas benefit of **92 kilotonnes each year**. We derived this figure using a spatial dataset of net greenhouse gas flux from Global Forest Watch.[143]

Storage

- **Soil**. The mean soil organic carbon density in the area is 63 tonnes per hectare according to spatial data from SoilGrid.[144] This translates into 561 kilotonnes across the whole property, or **2,059 kilotonnes.**
- **Biomass**. In coniferous forest in the montane cordillera ecozone, an average of 246 tonnes/hectare of carbon is stored in aboveground biomass according to data from the National Forest Inventory.[145] This translates to **2.2 megatonnes** across the Conservation Area. This is higher than other estimates of average carbon density for this ecozone: 240 tonnes/hectare across all sources (aboveground biomass, belowground biomass, dead wood, litter, and soil organic matter)[146] and 300 tonnes/hectare (of which 170 is inorganic soil carbon, 30 organic soil carbon, and 100 tree biomass).[147] Because the tree makeup at MBCA is different from the average make up across the ecozone (see Table 14), ecozone-wide estimates of average biomass carbon density may be inaccurate. Using the National Forest Inventory's merchantable biomass calculator and forest inventory data from Canfor that specifies species makeup, we estimated **995 kilotonnes in merchantable stands** in MBCA.

Using the $135 to $440 per tonne range provided in the recent federal Regulatory Impact Analysis Statement for the Clean Fuel Standard,[149] **we can estimate the value of the stock of carbon stored at the site at $345.7 million to $1.1 billion, and the value of the carbon sequestered at $12.4 million to $40.5 million each year.**

How much additional carbon is stored as a result of the cap on Canfor's harvest level, compared to industry standard harvest levels?

On average, Canfor has harvested 4660 m^3 per year so far, according to private internal data shared with us for this project. However, it is reasonable to assume that they will harvest the entire 800,000 m^3 by 2023 (the amount allocated by their agreement

Table 14. *Tree genus percentage by volume (merchantable timber only)*[148]

Genus	MBCA	Montane cordillera average
Fir	40	17
Pine	34	31.8
Spruce	15	25.2
Larch	9	1.5
Poplar	4	2.8
Birch	2	0.4
Cedar and other conifers	<1	2.6

***Table 15**. Area and estimated wood volume of private timber lands clear-cut in the Elk Valley.*[153]

Year	Area clearcut (hectares)	Estimated volume (m^3)
2015	1663.3	265,296
2016	2351.1	375,000
2017	1392.84	222,158
2018	1591.3	253,812
2019	2382.1	379,945

with NCC): according to their "sustainable forest management" plan,[150] Canfor aims to harvest 100% of the allocated volume for their major replaceable licenses. There are roughly 2,070 hectares of productive forest in the harvesting land base at MBCA, which means a harvest intensity of **3.9 m^3/hectare/year**.

The most appropriate counterfactual for logging activity at MBCA is logging activity on privately-owned land in the area. MBCA was privately owned before Shell donated it, and much of the logging in this region occurs on private land.[151] Unfortunately, up-to-date data on logging activity on private land is not available in this region. Fortunately, a 2021 analysis used remote sensing to identify how many hectares of the 46,000 hectares of Private Managed Forest Land in the Elk Valley were clear-cut each year from 2015-2019 (Table 15).[152]

To estimate the harvest intensity on private land in the Elk Valley, we used Canfor's forest inventory data to calculate the average merchantable wood volume per hectare in MBCA. We then assumed that this same volume was cut for each hectare clearcut on private land. There is an average of 159.5 m^3 of merchantable timber per hectare at MBCA (we took a weighted average of volume per hectare values for stands based on stand area). This means that each year, an average of **33 m^3/hectare/year** is logged on private timber land in the Elk Valley. This is an order of magnitude higher than the 3.9 m^3/hectare/year at MBCA.

What is the net carbon impact of this difference in harvest intensities? According to Canfor data and the NFI Biomass Calculator, there is an average of 0.76 tonnes of biomass (0.37 tonnes of carbon; 1.34 tonnes) per m^3 of merchantable timber at MBCA. By avoiding a harvesting regime similar to that seen on private land in the Elk Valley, the MBCA saves **80.7 kilotonnes each year**.

That said, logging activity at MBCA is more intensive than on Crown land in the area. MBCA is in the Cranbrook Timber Supply area, where the allowable annual cut is 808,000 m^3/year for a timber harvesting land base of 351,773 hectares.[154] This translates to **2.3 m^3/hectare/year**. Across the entire site, this means 3312 m^3 more per year of harvested volume, or **4435.4 tonnes of additional atmospheric carbon** each year than if Canfor adopted the harvest intensity stipulated on Crown land.

Discussion

The stored and sequestered carbon alone at the MBCA is enormously valuable, at **$345.7 million to $1.1 billion in stored carbon plus $12.4 million to $40.5 million in sequestration each year**. If Shell had not donated this property, it is possible that it could have been used to generate carbon offsets. While there is still some logging on this property, a rough estimate of logging intensity on private land in the Elk Valley suggests that 80.7 kilotonnes are saved each year by avoiding a private logging regime, which involves extensive clearcutting. That said, if logging practices were aligned with harvest intensities for Crown land in the region, 0.4 kilotonnes could be saved each year. Our estimate of logging intensity on private land is rough and relied on remote sensing research to supplement government data, which is not up to date.[155] Better data on logging activities on private land in different areas of Canada would be a valuable resource for NBS practitioners looking to estimate impact on carbon as well as third-party consultants doing formal analyses for carbon offset programs.

Once again, our analysis is only able to capture a small portion of the value created by this project through its impact on biodiversity. Our estimate of $47,600 in yearly fly-fishing revenue should be understood as a minimum estimate, and it only covers one type of tourism. While it seems unlikely that tourism businesses would provide funding for NBS projects, as they tend to be small local operations, these revenues should bolster support for NBS projects among government departments interested in economic development, particularly – but not exclusively – at the local government level. At a minimum, these numbers can help to combat the narrative that NBS projects reduce economic activity, jobs and tax revenue for resource-dependent regions like the Fernie area. On the contrary, they support a vibrant tourism industry. Since a substantial part of this project's value is not captured by economic metrics, traditional funders from the government and philanthropic sectors who are interested in the ecological and social value of projects like the MBCA are still essential.

We are unable to capture the impact of the project on other ecological features that impact tourism. For example, reduced logging rates and clear-cut logging make for more attractive views for tourists. And while the property does not have codified rules on logging in critical species habitat, in practice this is negotiated between NCC and Canfor, and NCC is often able to divert logging to less critical habitat.[156] We were also unable to capture the impact of logging on soil erosion, which can degrade habitat for westslope cutthroat trout and bull trout; erosion due to logging and mining have led to declining populations in the Elk Valley.[157] Analysis of logging activity on high-erosion-risk (steep) land near fish habitat would resolve this shortcoming.

Expenditures from other sources

Logging expenditures at MBCA generate 3.62 jobs and $780,000 in indirect economic output each year, according to our estimates (Table 18). Canfor did not provide expenditure data, so we used per-volume expenditures data from a report on the Cheakamus Community Forest in BC (Table 17) and adjusted them by the volumes logged at MBCA.

Table 16. *Impact on jobs (total) and economic output (millions of dollars) across Canada from 15 years (2006-2020) of expenditures on the Mount Broadwood Conservation Area*

Sector	Expenditure	Indirect output impact	Direct jobs impact	Indirect jobs impact
Air transportation	$50.00	0.00	0.00	0.00
Food services and drinking places	$872.74	0.00	0.02	0.00
Gasoline stations	$975.07	0.00	0.01	0.00
Grant-making, civic, and professional and similar organizations	$141,463.53	0.09	1.54	0.61
Legal services	$10,618.12	0.00	0.08	0.02
Management, scientific and technical consulting services	$68,282.10	0.03	0.61	0.20
Miscellaneous store retailers	$2,137.76	0.00	0.04	0.01
Non-store retailers	$129.88	0.00	0.00	0.00
Other transit and ground passenger transportation and scenic and sightseeing transportation	$252.76	0.00	0.00	0.00
Printing and related support activities	$6,232.64	0.00	0.05	0.02
Support activities for forestry	$19,782.50	0.01	0.12	0.05
Other municipal government services	$14,257.02	0.01	0.09	0.05
Traveller accommodation	$530.94	0.00	0.01	0.00
Total	**$265,585.06**	**0.14**	**2.57**	**0.95**

Economic impacts

Project expenditures

MBCA has spent $265,585.06 in operating expenditures over the past 15 years. MBCA generated $37,181.90 in indirect economic output, 2.57 person-years of direct jobs, and 0.95 person-years of indirect jobs over the course of the past 15 years, according to our estimate (see Table 16). We obtained the estimates in Table 16 by classifying expenditure data provided by NCC into the sector categories used by Statistics Canada and multiplying sectoral expenditures by the "all provinces" multipliers for each sector (see Appendix B).

What would the economic impact of the angling industry potentially supported by MBCA be? We estimated $47,600 in yearly revenue, which would go to the "Amusement and recreation industries" category. By applying the multipliers in Appendix B, we estimated indirect output of $30,000, 0.66 direct jobs, and 0.21 indirect jobs each year. For the expenditures of the outfitter we spoke to (rather than hypothetical expenditures by recreational fishing businesses across the MBCA), we estimated 0.17 direct jobs and 0.05 indirect jobs each year. This seems realistic: the outfitter pays their guides $300 a day and estimates a yearly average guide-to-guest ratio of 1:0.83 (65% of trips are one-on-one, and the rest are two-on-one). This means, over 28 days, $6,930 is spent on guides each year. The outfitter also employs the proprietor, who acts as a guide and manager and manages a winter-season business.

Table 17. *Per-volume expenditure assumptions for logging activities (2017 dollars).*[158]

Sector	$/m³
Architectural, engineering and related services	6.50
Forestry and logging	96.09
Office administrative services	0.61
Other federal government services (except defence)	0.25
Repair construction	2.00
Support activities for forestry	3.50
Transportation engineering construction	6.23

Table 18. *Yearly impact on jobs (total) and economic output (millions of dollars) across Canada from logging expenditures in the Mount Broadwood Conservation Area, using per-volume logging expenditure data from the Cheakamus Community Forest (see Appendix B for multipliers).*[159]

Sector	Expenditure	Indirect output impact	Direct jobs impact	Indirect jobs impact
Architectural, engineering and related services	$52,000	0.02	0.357	0.143
Forestry and logging	$768,720	0.69	1.944	2.868
Office administrative services	$4,880	0.00	0.037	0.013
Other federal government services (except defence)	$2,000	0.00	0.012	0.005
Repair construction	$16,000	0.01	0.116	0.050
Support activities for forestry	$28,000	0.02	0.174	0.065
Transportation engineering construction	$49,840	0.04	0.202	0.203
Total	**$921,440**	**0.78**	**2.84**	**3.35**

Discussion

The most notable economic impacts of MBCA are from tourism. Project expenditures have a modest impact on jobs and economic output: 3.52 direct and indirect jobs (mostly within NCC) and $140,000 in indirect economic output from a total expenditure of $265,585.06 over 15 years. But the yearly impact of expenditures by the angling outfitter we looked at (0.22 jobs per year) is substantial given that it is one small, local operation of which there are many in the area. The MBCA property manager noted that, while this is the only angling outfitter who has signed an agreement with the NCC, he knows that other guides use the property, as well as many independent recreational fishers who likely pay for local accommodation and provisions. Unfortunately, the input-output multipliers provided by Statistics Canada group hunting and fishing guides together with other "amusement and recreation industries" including operators of video gaming terminals and lotteries. These are different industries with different expenditure profiles and labour needs; more granular multipliers for environmental and nature-related economic activities, including a dedicated multiplier category for hunting and fishing guides, would be very useful.

Logging activities on the property also generate jobs and output: $780,000 in indirect economic output and 6.19 jobs each year with $921,440 in expenditure. We do not treat these impacts as project impacts per se, because this is not a conservation forestry project. Rather, logging activities were one of the conditions for the donation of the land. To compare the jobs impacts of logging and nature tourism properly and identify the appropriate balance between them, we would need more information about the long-term impacts of Canfor's logging activities and the way it affects tourism. It is also worth noting that we used per-volume logging expenditure data from another part of BC, where the forest and economy are different; it would be better to use local data. The Government of BC collects logging expenditure data through the Interior Logging Cost Report,[160] and while individual expenditures might be proprietary, there is no reason why the government should not publish aggregate expenditure breakdowns, which would allow researchers to better understand the economic impacts of logging as compared to other land uses.

4.3 Potato farming on PEI

Location: Near Kensington, Prince Edward Island

Size: Around 800 hectares, with 263 hectares of potatoes

This case study focuses on a PEI farm that produces potatoes, beef, and cereals and forage to feed livestock. The owners engage in three main "beneficial management practices" (BMPs) with environmental benefits:

- **Minimizing tillage** in non-potato parts of their crop rotation
- Planting winter rye as a **cover crop** following earlier-season potato varieties
- Reducing the application of nitrogen fertilizer through "4R" **nutrient management**, notably using slow-release nitrogen sources and split application of nitrogen over the course of the potato operation.

The owners have implemented these BMPs over the course of decades as their understanding has developed and new technologies have become available, rather than implementing them all at once. The owners were initially motivated by a desire to improve soil health and have more recently added the reduction of atmospheric greenhouse gases to their list of priorities.

Ecosystem services

There is evidence that the three BMPs used on the farm provide a number of valuable ecosystem services:

- Minimizing tillage can build soil organic matter, improving productivity and soil carbon sequestration among other benefits, depending on conditions.[161]
- Winter rye cover crops can build soil organic matter and reduce erosion, water loss, and nutrient leaching.[162] They can reduce greenhouse gas emissions and improve yield of the subsequent cash crop.
- Nutrient management reduces the use of nitrogen fertilizer which contributes to many environmental problems, including N_2O emissions, nitrogen leaching into groundwater, and NH_3 volatilization. Nitrogen fertilizer also affects carbon mineralization from soil, either positively or negatively depending on conditions.[163]

We focus on the value created by these BMPs through their effect on greenhouse gas emissions and soil erosion, since there is evidence that these ecosystem services are affected by the BMPs, they are valuable, and there are methods and data sources available to estimate both ecological and economic values.

Photo credit: arodPEI

Table 19. *RUSLE parameter values for the farm examined in this case study.*

RUSLE parameter	Farm value
Soil loss (tons per acre per year)	0.58 without cover cropping; 0.67 without it
Rainfall and runoff	84 (Summerside)
Soil erodibility	0.30 (Charlottetown soil, 3.01% organic matter)
Slope length and steepness	9%; 72 feet
Crop management	0.21 (four-year rotation with potatoes with a winter cover following row crops with spring plowing; silage corn with winter cover following row crops with manure applied; small grain following a low residue crop (corn silage, potatoes); hay - direct seeding in spring following low residue crop)
Support practices	0.3 (strip cropping and three-year rotation)

Soil erosion

The impact of cover cropping on soil loss through water erosion can be estimated using the Revised Universal Soil Loss Equation (RUSLE) (see Table 19). Data on the parameters of the equation are available from information sources provided by the Government of PEI[164] and information supplied by the farmer, except for information on the length and grade of the longest slope on the property. We used the average slope in the area based on the PEI Detailed Soil Survey[165] (7%) and assumed a slope length of 72 feet because this is the value used for the standard plots on which the RUSLE equation is based.[166]

The RUSLE indicates avoided soil loss of **236.7 tonnes per year** through the use of cover cropping. Evidence from PEI suggests the loss of $6.94 in nutrients per tonne of soil loss,[167] which would translate into **$1,642.70 per year in avoided nutrient loss** on the farm based on replacement costs alone.

Greenhouse gas uptake

The Prince Edward Island Federation of Agriculture (PEIFA) has compiled equations for calculating the emissions reductions associated with various agricultural beneficial management practices.[168] The farm's three BMPs align with four BMPs in the PEIFA guide:

- Reduced intensity, depth, and frequency of tillage
- Cover cropping in potato production systems
- Site-specific 'right rate' nitrogen recommendations
- Use of enhanced efficiency fertilizers

Using the equations provided by PEIFA, the emissions reductions associated with the use of these BMPs across 263 hectares of potato crops are as follows:

Reduced intensity, depth, and frequency of tillage

- **CO_2**: The farm uses a chisel plough in spring rather than a mouldboard plough in the fall. Evidence from potato farming in PEI[169] suggests that this transition can reduce emissions by 1,920 tonnes.
- **N_2O**: By not ploughing the fall crop, 250 tonnes per year could be avoided from residue decomposition. Reduced fertilizer needs for the potato crop could reduce N_2O emissions by 197.3 tonnes each year.

Cover cropping in potato production systems

- **CO_2**: The farm uses a non-leguminous cover crop where the crop is not established prior to the harvest, potentially reducing emissions by 96.5 tonnes per year by increasing soil organic matter.
- **N_2O**: The farm could reduce by 39.7 tonnes per year through the uptake of nitrate in the soil and 5.5 tonnes per year through reduced nitrate leaching.

Nutrient management

- **Use of enhanced efficiency fertilizers**
  - **N_2O**: The farm uses slow-release nitrogen sources. Assuming they reduce fertilizer needs by 15%, the farm could reduce emissions by 152.5 tonnes each year.
  - In reality, this number depends on the mode of action, soil type, and management factors. For example, irrigated fields see greater reductions than rain-fed fields, and the use of no-till undermines reductions.
- **Site-specific 'right rate' nitrogen recommendations**
  - **N_2O**: This could reduce emissions by 297.2 tonnes per year.

Using the $135 to $440 per tonne range provided in the recent federal Regulatory Impact Analysis Statement for the federal Clean Fuel Standard,[170] we can estimate the value of reduced atmospheric greenhouse gas emissions at **$259,200 to $844,800 when the BMPs are first implemented and $140,224.50 to $457,028.00 each year**.

Discussion

It is difficult to provide general guidance on estimating the value of ecosystem services generated by agricultural BMPs, because they depend so much on region, crop, and crop management decisions. For this case study, we were able to use informational materials compiled by the government of Prince Edward Island that adapted broader scientific understanding to local soil, weather, and farming patterns. This type of material is a great resource for practitioners looking to estimate the economic benefits of agricultural BMPs.

The farmer noted that of the three BMPs, all but cover crops paid for themselves through reduced input costs. While cover cropping saved $1,578.79 each year in lost nutrients, according to our estimate, the farmer estimated costs of $16,298 each year for cover cropping. Our measure of the value for farmers of reducing soil erosion is conservative, and a more comprehensive measure – for example, one that looked at long-term soil health impacts on productivity, rather than just nutrient costs – would likely produce a larger number. Even so, the private value of ecosystem services associated with cover cropping may be less than costs; in this case, it would be important to document public value. For example, cover cropping reduces the amount of nutrient runoff, which can make well water unsafe to drink and cause eutrophication in waterways.[171] Estimating the value of cover cropping for these purposes would require more public data is needed on nitrate removal costs from well water and inland and estuarine waterways. But enabling these estimates could help make the case for public spending (from federal, provincial or municipal governments) to help offset costs to farmers from cover cropping.

Economic impacts

Expenditures on the three key BMPs generate 1.93 jobs and $60,000 in indirect economic output each year, according to our estimate (Table 21). We obtained the estimates in Table 21 by classifying expenditure data provided by the farmer (some from financial statements, some from his memory) into the sector categories used by Statistics Canada (see Table 20) and multiplying sectoral expenditures by the "all provinces" multipliers for each sector (see Appendix B).

Table 20. *Expenditures associated with beneficial management practices (BMPs)*

BMP	Description	Expenditure	Sector
Cover cropping	Landoll	64,900 over 15 years	Machinery, equipment, and supplies merchant wholesalers
	Seed	18 per acre	Miscellaneous merchant wholesalers
	Labour	12 per acre	Crop production (except cannabis, greenhouse, nursery and floriculture production)
	Equipment	12 per acre	Machinery, equipment, and supplies merchant wholesalers
	Other agronomic services	5,000-10,000 each year	Management, scientific, and technical consulting services
Low-till	Synkro	35,000 over 15 years	Machinery, equipment, and supplies merchant wholesalers
	Roundup	10 per acre	Miscellaneous merchant wholesalers
Low-till, nutrient management	Satellite subscription for GPS	3,641.83 each year	Telecommunications
	Machine maintenance	Reduced, but unknown	Automotive repair and maintenance
	Machine fuel	Reduced, but unknown	Miscellaneous merchant wholesalers
	Labour	Reduced, but unknown	Crop production (except cannabis, greenhouse, nursery, and floriculture production)
	GPS system	38,600 over 15 years	Machinery, equipment, and supplies merchant wholesalers
Nutrient management	Fertilizer spreading	Increased, but unknown	Support activities for crop and animal production
	Fertilizer	Reduced, but unknown	Miscellaneous merchant wholesalers
	Site-specific soil sampling	5,000-10,000 each year	Support activities for crop and animal production

Table 21. *Yearly impact on jobs and economic output (millions of dollars) across Canada from expenditures on our three "beneficial management practices" at the farm (see Appendix B for multipliers)*

Sector	Expenditure	Direct jobs impact	Indirect jobs impact	Indirect output
Crop production (except cannabis, greenhouse, nursery, and floriculture production)	$24,000.00	0.121	0.093	0.018
Machinery, equipment, and supplies merchant wholesalers	$33,233.33	0.43	0.08	0.01
Miscellaneous merchant wholesalers	$56,000.00	0.71	0.16	0.02
Management, scientific, and technical consulting services	$7,500.00	0.075	0.023	0.003
Support activities for crop and animal production	$7,500.00	0.211	0.009	0.002
Telecommunications	$3,641.83	0.007	0.006	0.001
Total	**$131,875.16**	**1.56**	**0.37**	**0.06**

Based on the farmer's opinion and a comparison of potato yields from the farm with average per-hectare yields for Prince Edward Island,[172] the use of these BMPs does not seem to significantly affect the productivity of the potato operation. Because of this, we do not analyze the economic impact of changes in productivity.

Discussion

The farmer was unable to recall some important expenditure details that would capture costs and savings associated with BMPs. The farmer noted that nutrient management reduced the amount of fertilizer required, but we were unable to capture this in expenditure data because fertilizer purchases were grouped together with fertilizer spreading services, which grew slightly more costly under the nutrient management BMP. We were also unable to capture cost savings associated with low-tillage farming, because the farmer did not remember how much he saved in fuel and maintenance – only that the costs were lower. This type of data could be easily gathered through a survey of farmers in a specific region, and it would be invaluable in informing policies to encourage BMP uptake.

4.4 Thaidene Nëné National Park Reserve

Location: Łutsël K'é, Northwest Territories

Size: 1,407,000 hectares

Thaidene Nëné National Park Reserve (TNNPR) was created in 2019. It is connected to a Territorial Protected Area (910,500 hectares) and a future wildlife conservation area (312,000 hectares). A unique feature of the park is that it is funded by a $30 million trust fund created with half of the money raised by Łutsël K'é Dene First Nation through private sources and half from the federal government. The interest and investment income from the trust fund supports operations and maintenance activities such as training, salaries, and youth engagement. The Park is stewarded by the Ni Hat'ni Dene Guardians, where members of the Łutsël K'é Dene First Nation monitor and document the environment and visitor activity and cultivate and transmit cultural and scientific knowledge about the land to the community.

Ecosystem services

Greenhouse gas uptake

This park is not eligible for voluntary or regulatory carbon offsets because there was no immediate threat that it would be converted to another land use.

According to data from SoilGrids[173] the mean stock of soil organic carbon per hectare within the park is 44.5 tonnes. This translates to 229.78 megatonnes stored in soil in the park.

According to data from the National Forest Inventory 9.25 tonnes per hectare of carbon are stored above ground in the Taiga Shield ecozone, or 33.95 tonnes per hectare.[174] This translates to 47.77 megatonnes across the entire park.

According to data from Global Forest Watch,[175] forests within the park sequester 1,206 tonnes more than they emit each year.

Discussion

Since there was no immediate threat of land conversion at the time the park was formed, our estimates of the value of greenhouse gas uptake do not represent avoided emissions which could be counted towards greenhouse gas reduction commitments or converted into revenue through the sale of offsets. These numbers are likely to be of most interest to traditional funders of conservation in government and the philanthropic sector. But these numbers indicate that there is a vast amount of carbon stored in the park – particularly in soil – as is the case across Northern Canada.[176] **This highlights the importance of developing alternative mechanisms to finance conservation of Northern landscapes without waiting for the threat of development to arrive.**

As in the other case studies, habitat and biodiversity are an important blind spot for the economic metrics in this report. The value of many of the environmental benefits of this park is difficult to quantify using economic metrics. TNNPR covers a unique, rich, and diverse landscape that provides critical habitat for threatened species such as Barren ground caribou. It supports the subsistence of locals and allows the continuance of the traditional Dënesųłiné ways of life. There have been many interesting, informative attempts to estimate the economic value of increased biodiversity for various human uses[177] and for traditional subsistence in particular.[178] With better data on tourist activity in TNNPR, it would likely be possible to estimate the value of conserved species for tourism, potentially generating more interest from government agencies interested in economic development or tourism operators. But, in general, these studies tend to rely on non-market valuation methods, meaning they are likely to be of primary interest to traditional funders.

Economic impacts

Project expenditures

One-time expenditures on the establishment of TNNPR may have resulted in a one-time impact of 16.4 direct jobs, 50 indirect jobs, and $10,750,000 in indirect economic output. And subsequent operational expenditures may result in yearly impacts of 13.2 direct jobs, 7.1 indirect jobs, and $1,483,000 in indirect economic output. This is in the same range as other estimates: one projected "18 positions, including at least 5 full-time, year-round jobs" in the surrounding community.[179] Table 22 presents these estimates.

Utsingi Point, East arm of Great Slave Lake, Canada.
Photo credit: Paul Gierszewski

Table 22. Yearly and one-time impacts on jobs (total) and economic output (millions of dollars) across Canada from expenditures on Thaidene Nënë National Park Reserve (see Appendix B for multipliers)

Sector	Expenditure	Direct jobs impact	Indirect jobs impact	Indirect output impact
Yearly				
Electric power generation, transmission, and distribution	$65,380.00	0.13	0.11	0.040
Printing and related support activities	$5,539.71	0.03	0.02	0.004
Accounting, tax preparation, bookkeeping, and payroll services	$116,468.81	0.71	0.29	0.061
Legal services	$116,468.81	0.45	0.17	0.035
Business support services	$494,433.41	5.88	1.12	0.215
Air transportation	$234,328.15	0.46	0.76	0.193
Miscellaneous store retailers	$124,649.23	1.37	0.28	0.059
Repair construction	$10,159.53	0.03	0.03	0.007
Transportation engineering construction	$177,004.30	0.53	0.57	0.145
Automotive repair and maintenance	$8,325.51	0.07	0.02	0.004
Motor vehicle and parts dealers	$8,325.51	0.04	0.01	0.002
Other federal government services (except defence)	$1,138,917.02	3.47	3.76	0.720
Yearly total	$2,500,000.00	13.19	7.14	1.483
One-time capital expenditure				
Non-residential building construction	$12,000,000.00	16.36	49.99	10.75

We were unable to obtain expenditure data for TNNPR, but we constructed estimates based on publicly-available projections of TNNPR expenditures and expenditure data from other parks in the Northwest Territories, like Nahanni National Park Reserve. Estimates suggest TNNPR required $12 million in initial capital investment and $2.5 million in yearly expenditures for the first 12 years.[180] The initial capital investment was to be spent on "a visitor centre and administrative offices (potentially housed in the same building), and over time, expand to include one or more patrol and/or monitoring cabins, campsites, and other recreational infrastructure (e.g., a trail network, emergency shelters)."[181] Based on this description, we assign the initial $12 million expenditure to the "non-residential building construction" category. To determine the allocation of yearly expenditures, we calculated the percentage of operational expenditures spent on different sectors by other national parks in the Northwest Territories (Table 22).[182]

Visitor expenditures

Expenditures by park visitors may result in 23.6 direct jobs, 16.6 indirect jobs, and $3,355,000 in indirect economic output across Canada each year, according to our estimate. The majority of these impacts would be local. Against the background of limited jobs in the region, these numbers are significant.

We were unable to obtain visitor expenditure data for TNNPR, so we used data from Nahanni National Park Reserve, the most comparable national park in the Northwest Territories to TNNPR in terms of accessibility and likely visitation.[184] Table 23 presents these expenditures, classified by sector, and impacts calculated by multiplying sectoral expenditures by the "all provinces" multipliers in Appendix B. Projections suggest that TNNPR could "easily meet or surpass Nahanni's visitation levels."[185]

Table 23. Allocation of yearly expenditures in national parks in the Northwest Territories in 2008/2009[183]

Description	Sector	Percent
Public utilities	Electric power generation, transmission and distribution	2.62
Printing and publications	Printing and related support activities	0.22
Professional services	Accounting, tax preparation, bookkeeping and payroll services	4.66
	Legal services	4.66
Business services	Business support services	19.78
Travel	Air transportation	9.37
Supplies	Miscellaneous store retailers	4.93
Other expenditures	Miscellaneous store retailers	0.06
Repairs & renovations	Repair construction	0.41
Staff housing	Residential building construction	0.00
Non-residential construction	Non-residential building construction	0.00
Access roads/ parking	Transportation engineering construction	7.08
Other engineering	Other engineering construction	0.00
Fleet and major	Automotive repair and maintenance	0.33
	Motor vehicle and parts dealers	0.33
Wages and salaries	Other federal government services (except defence)	45.56
Total		100.00

Table 24. Yearly impacts on jobs (total) and economic output (millions of dollars) across Canada from visitor expenditures in Nahanni National Park Reserve in 2008-2009 (2017 dollars[186]) (see Appendix B for multipliers)[187]

Sector	Expenditure	Direct jobs	Indirect jobs	Indirect output
Amusement and recreation industries	2,407,799.00	14.99	9.34	1.681
	81,000.00	0.50	0.31	0.057
Air transportation	1,323,000.00	2.59	4.31	1.088
Traveller accommodation	315,900.00	3.08	0.96	0.192
Food services and drinking places	264,600.00	2.31	1.18	0.230
Insurance carriers	111,275.00	0.15	0.49	0.108
Total	4,503,574.00	23.63	16.60	3.355

Discussion

These estimates make clear that the park has the potential to have an enormous economic impact in the region. However, the numbers do not tell the whole story, either. The methods we outline for estimating economic impact have the benefit of producing a metric that can be compared between projects. Still, this comparability is limited by the park's special circumstances. To begin with, "every job outside of Yellowknife is like 10 jobs in Yellowknife," as former Northwest Territories Finance Minister Michael Miltenberger said in 2013.[188] Not only does the park create jobs in a remote community, but some of these jobs allow community members to practice and teach traditional Dënesųłiné ways of life. There are currently four community members employed to monitor and steward the land and practice and teach traditional subsistence practices through the Ni Hat'ni Dene ("Watchers of the Land") program. A 2016 study used interviews and social return on investment methodology to estimate the value of the program for employees, community members, NGO stakeholders, and government, and found a return on investment of 2.5:1 that was expected to grow over time.[189] This estimate is based on extensive interviews within Lutsel K'é, an important step because these social values are so subjective and regionally specific. And by bolstering the ability of community members to pursue a traditional subsistence lifestyle, the program and park likely change the very meaning of "jobs" in the community of Lutsel K'é. These additional considerations need to be layered on top of standard economic impact analysis for remote and Indigenous communities.

5. CONCLUSION

There is an opportunity to increase the funding available for conservation, restoration, and improved management of nature by estimating and communicating the economic benefits of these projects. This guidebook aims to familiarize NBS practitioners with two types of economic metrics that are popular among a range of potential funders: 1) revenue streams and cost savings from ecosystem services, and 2) impacts on local jobs and economic output. We identify accessible methods and demonstrate the analysis on four case studies: a wetland restoration project in Ontario, a mixed-use forestry and conservation project in British Columbia, a low-tillage farming operation on Prince Edward Island, and a protected area in the Northwest Territories.

We find that:

It is common practice to use estimates from other project sites, but this must be done carefully to maintain credibility. NBS practitioners can avoid major inaccuracies by following a few best practices:

- The value of revenue and cost savings from ecosystem services depends on site size and surrounding land uses. Transferred estimates should be adjusted accordingly.
- Impacts on local jobs and output depend on local economic structure and a project's inputs. It is better to make a crude estimate than to transfer a sophisticated but dissimilar estimate. If you do transfer an estimate, prioritize finding a similar economic context and a project with similar labour requirements over a similar ecological context.

Even with our conservative methods and narrow focus, the economic value created by NBS projects is substantial. This suggests substantial potential to attract funders who are interested in the economic metrics we used but who do not currently fund NBS projects.

There are gaps in publicly available data that make it difficult to estimate the business case for NBS projects, undermining NBS practitioners' ability to highlight the value of these projects.

- Statistics Canada's input-output multipliers, which can be used to estimate impacts on jobs and economic output, use categories of economic activity that do not map well to the activities associated with NBS projects. A set of input-output multipliers tailored to NBS projects would be helpful, particularly if they focused on local impacts. For example, environmental consulting is currently grouped with management consulting, and fishing and hunting guides are currently grouped with other amusement and recreation services.

- Federal and provincial governments already collect data that would help NBS practitioners if they were made public. For example, aggregate data on the average allocation of expenditures by green infrastructure projects funded through programs like the Disaster Mitigation and Adaptation Fund or by logging operations on Crown lands would facilitate estimates of the economic impacts of these activities.

Even with our conservative methods and narrow focus, the economic value created by NBS projects is substantial.

- Where biophysical data are publicly available, they are often in a format that is inaccessible to non-experts and is difficult to link to economic data for the purpose of ecosystem service valuation.

- More public data on the costs of built infrastructure, particularly for water filtration and flood management, would facilitate estimation of any cost savings that NBS projects might offer by replacing or extending the lifetime of built infrastructure.

APPENDIX A - ECOSYSTEM SERVICE MODELS AND TOOLS

This is a selected list of tools and models for ecosystem service valuation. The Tool Assessor provided by the Ecosystems Knowledge Network is also a great resource for finding and comparing ecosystem service valuation tools.

Table 1. Selected tools for ecosystem service valuation

Model	Use	Benefits	Limitations
Revised Universal Soil Loss Equation, version 2 (RUSLE2)	Estimating rates of water erosion of soil	Easy to use Free Ontario version has built-in data	Windows only
Erosion-Productivity Impact Calculator (EPIC)	Estimating crop productivity impacts of erosion	Can estimate at the hectare scale and accommodate information about local conditions	Data-intensive and requires modelling expertise
Crop Environment Resource Synthesis (CERES)	Estimating crop productivity impacts of erosion as well as other changes in soil, climate, genotypes, and management	Provides accurate, detailed estimates	Data-intensive and requires modelling expertise
Co$ting Nature	Ecosystem service mapping tool that covers ecosystem services from water, carbon, nature-based tourism, and hazard mitigation	Free version available Uses globally available default datasets but can accommodate better data if available	Requires some expertise to use Does not generate economic values for ecosystem services
Vegetation Indices	General spatial planning and evaluation of greenspaces Residential proximity and abundance Use with local socio-economic and demographic data in NBS project design	Standard measurements; easy to replicate Short-time scale and wide range of resolutions Suitable for planning and monitoring from micro- to meta-scale	High technical and financial costs Unable to assess greenspace quality Unable to assess usage types; frequency Unable to remove private land/gardens from data Does not directly measure community health benefits
Land use database	Measuring the distribution, type, and quality of public greenspaces Evaluating potential social and mental health impacts Evaluating potential access patterns based on greenspace type Government of Canada (2015) Land Cover Canada uses a 30m resolution, which addresses most accuracy concerns	Measure greenspace quality, type and landscape level integration Measure public/private distribution of greenspace Better accuracy for measuring community greenspace access	Does not directly measure community health benefits Does not account for socio-economic and physical access barriers Limited ability to account for gray infrastructure intrusion and integrated green infrastructure – i.e. street trees Accuracy of abundance measurements are resolution dependent Long-time scales can cause greater inaccuracy
Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)	Calculates forest carbon stocks and changes in them over time based on data about forest characteristics	Free with detailed guidance and graphical user interface	Requires detailed forest data Difficult to use without expertise
National Forest Inventory Biomass Calculator	Calculates forest biomass, which can be used to estimate carbon	Can be used with basic data (tree species breakdown) or more detailed, stand-level data	Static estimates only

USDA i-Tree	iTree My Tree and Design can collect crowdsourced local data. Good for micro-scale projects iTree Eco is useful for quantifying benefits from urban tree cover iTree Eco is populated with default datasets, but local data is strongly recommended	Free software suite with step-by-step guidelines Developed by USDA and in use since 2006 Many examples of usage in Canadian urban forestry plans	Dependent on the availability of local data sets iTree eco is adapted for use in Canada. Other tools in the suite can be adapted for use in Canada at an additional cost
Open Tree Map	Useful to develop natural asset inventories at a relatively low-cost Crowdsourcing data can be used as an innovative community engagement strategy	Ability to crowdsource local tree data at a relatively low-cost Can also be used to management other types of green infrastructure	Use is based on a price-per-tree model. Can cost more than $40,000/year to analyze the benefits of urban woodlands
Sustainable Asset Valuation (SAVi)	SAVi can be useful for directly valuing health co-benefits of existing natural infrastructure Help integrate health consideration when considering green v. gray alternatives	Can be run during different project phases Values co-benefits outside traditional project valuation methods Already applied in Canadian context (Pelly's Lake, MB) Support available from IISD	Highly technical; requires extensive local datasets Required data collection may be cost-prohibitive
InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)	A suite of tools for mapping ecosystem service provision and value, using spatial (map) and non-spatial (table) data inputs	Free and open-source Results can be expressed in biophysical or economic terms	Requires basic to intermediate skills in GIS software
Protected Areas Benefits Assessment Tool+ (PA-BAT+)	Useful for evaluating policies and procedures in established protected areas; and key ecological areas with unofficial status	Designed for universal application Works well under specific local conditions; ecological contexts Provides an assessment of benefits for different stakeholder groups Low-cost, rapid assessments	Results are based on local knowledge > biophysical data Benefits are not quantified; can cause over/underestimation Intended for single-site use
Toolkit for Ecosystem Service Site-Based Assessment (TESSA)	Rapid, low-cost assessments to determine significant site-level ecosystem services Can be used to identify key stakeholders, beneficiaries Can determine maximal value and net consequences for site-level planning Can evaluate trade-offs and synergies between different ecosystem services to inform more detailed assessments and local mapping	Comprehensive framework and step-by-step guidelines Can provide both qualitative and quantitative value of ecosystems Value of ecosystem services are low-cost and robust enough to use in decision-making No specialist knowledge required	Assessment scope is limited Assessment results are static representations of benefits (current or proposed) Long-term sustainability, natural asset discount rates and future resilience are not included in outputs No spatial output
Ecosystem Services Toolkit (EST)	Can support general ecosystem service assessments Priority ES Screening Tool is an effective rapid assessment tool Can be used at larger scales Can be used to inform decision-making processes	Provides step-by-step guidelines Integrates diverse valuation methods and software-based modelling tools Informs on strategies to incorporate ecosystem service assessments into land use planning, impact assessments and conservation incentives	Highly technical and comprehensive guidelines Selection of tools and valuation methods are user dependent - requires specialization

APPENDIX B - JOBS AND ECONOMIC OUTPUT MULTIPLIERS

See accompanying spreadsheet with job and output multipliers for economic sectors that commonly receive expenditures from projects pursuing nature-based solutions.

See spreadsheet

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ENDNOTES

1 NBS practitioners can include environmental NGOs, Indigenous communities, municipalities, conservation authorities, and other landowners or rights holders seeking to conserve, restore, or sustainably manage natural systems.
2 Deutz, A., Heal, G., Niu, R., Swanson, E., Townshend, T., Li, Z., Delmar, A., Meghji, A., Sethi, S., & Tobin-de la Puente, J. (2020). *Financing Nature: Closing the Global Biodiversity Financing Gap*. Paulson Institute. https://www.paulsoninstitute.org/wp-content/uploads/2020/09/FINANCING-NATURE_Full-Report_Final-Version_091520.pdf
3 Nair and Rutt (2009); Edwards (2013); Thomas (2016); Dasgupta (2021:464); O'Callaghan and Murdock (2021)
4 The Municipal Natural Assets Initiative has documented several such case studies (Cairns, 2020)
5 IBC (2018)
6 ICE (2018)
7 Chow-Fraser (2020)
8 TNLA (n.d.)
9 O'Callaghan and Murdock (2021)
10 CICC (2021)
11 ibid
12 Drever et al (2021)
13 Crouse et al (2017)
14 Some newer funding programs, like the federal Natural Infrastructure Fund, place more emphasis on accounting for co-benefits. This is a positive step.
15 IIAC (2020)
16 DUC (2020)
17 e.g., ibid
18 Bourque et al (2021)
19 ECCC (2020)
20 e.g., Donovan and Butry (2009)
21 Laurans et al (2013)
22 Spangenberg and Settele (2010)
23 Cairns (2020)
24 Boyd and Banzhaf (2007)
25 ibid
26 Kroeger et al (2017)
27 Ivanic et al (2020)
28 Boyd and Banzhaf (2007)
29 e.g., Won Kim et al (2003)
30 Brander et al (2013)
31 Boyd and Banzhaf (2007)
32 Brander et al (2013); Rosenberger and Stanley (2006)
33 Pattinson et al (2011); Brander et al (2013); Simpson (2017); Alamanos and Papaioannou (2020)
34 Simpson (2017)
35 e.g., Brander et al (2013)
36 Statistics Canada (2016)
37 Census Mapper (2021)
38 e.g., ibid
39 G-Econ (2021)
40 e.g., Great Bear Rainforest – see Chan et al., (2009)
41 Mitchell et al, (2021)
42 e.g., Brander et al, (2013)
43 Alamanos and Papaiannou (2020)
44 Loomis (1992)
45 e.g., Grady and Muller (1988); Bess and Ambargis (2011)
46 Statistics Canada (2020)
47 Patriquin et al (2003)
48 e.g., Nielsen-Pincus and Moseley (2010)
49 e.g., Patriquin et al (2003)
50 Statistics Canada (2020)
51 e.g., Wolthausen et al (2010)
52 Edwards et al (2013)

53 Values from Bivens (2019) and Statistics Canada (2020)
54 Values from Statistics Canada (2020)
55 See Neubauer and Megonigal (2015) for a summary; Bridgham et al (2006) on the carbon balance in North American wetlands; Thomson et al (2012) for an overview of N_2O fluxes; Le Mer and Roger (2001) and Dutaur and Verchot (2007) for an overview of CH_4 fluxes in soil, and Chapuis-Lardy et al (2007) for the same for N_2O.
56 Petrescu et al (2015)
57 ECCC (2019)
58 Neubauer and Megonigal (2015)
59 E.g., Petrescu et al (2015)
60 Table from Neubauer and Megonigal (2015)
61 For evidence from forests, for example, see Johnston et al (2019)
62 Mitsch et al (2013); Davidson et al (2019)
63 GFW (2021)
64 Kolka et al (2018)
65 Anderson-Teixeira et al (2018)
66 FAO (n.d.)
67 NFI (2021)
68 NFI (2021)
69 SoilGrids (2021)
70 Sothe et al (2021a; 2021b)
71 NFI (2017)
72 Bramley (2021); Sothe et al (2021a)
73 Harris et al (2021)
74 From Blanco-Canqui et al (2015)
75 E.g., Hansen (2009)
76 E.g., Living Carbon Investments et al (2014); 3GreenTree Ecosystem Services, Ltd and Nature Conservancy of Canada (2014)
77 ICAP (2021)
78 Sullivan et al (2020)
79 GoBC (2018)
80 GoC (2021)
81 Donofrio et al (2021)
82 Wang et al (2019)
83 ECCC (2020)
84 GoC (2020)
85 Cho (2021)
86 Samson and Rivers (2020)
87 Weitzman (2014)
88 Page et al (2020) examine eight sites, at which one the wetland is the next source of phosphorus rather than a sink. This outlier weighs the average value down significantly. Without this outlier, the average value is 13.4 kg/ha/year.
89 Alamanos and Papaioannou (2020); Walton et al (2020)
90 Wang and Mitsch (1998)
91 Dunne et al (2015)
92 From Alamanos and Papaioannou (2020)
93 see, e.g., Olewiler (2004); Pattinson et al (2011)
94 Widney et al (2017)
95 e.g., Olewiler (2004); Berry (2016)
96 This information was obtained by phone from the municipality in May, 2021
97 See Berry (2016) and Widney et al (2018)
98 e.g., Dunne et al (2015)
99 E.g., Fox and Dickson (1990)
100 E.g., Barbier (2013)
101 Fox and Dickson (1990)
102 Hunt et al (2005)
103 ibid
104 See Aziz and van Cappellen (2019) for an application in Ontario
105 EKN (2021)
106 e.g., Hunt et al (2005)
107 e.g., Shrestha et al (2002); Rolfe and Prayaga (2007); Yamazaki et al (2013)
108 FPTGC (2014)

109 Wall et al (2002)
110 Adhikari and Nadella (2011)
111 Carr et al (1991); Wall et al (2002)
112 See Wall et al (2002) for more information
113 AAFC (2021)
114 Statistics Canada (2021)
115 Wall et al (2002)
116 PEIAF (2003); Stone and Hilborn (2015)
117 OMAFRA (2021)
118 Battiston et al (1987); Pimentel and Burgess (2013)
119 e.g., Bremer et al (2008) for wheat and corn in Canada
120 e.g., Battiston et al (1987); Verity and Anderson (1990); Bremer et al (2008)
121 e.g., Fox and Dickson (1990)
122 e.g., Lobb (2016)
123 Data from Riley (1994) and Byun et al (2018)
124 Strachan et al (2015)
125 Petrescu et al (2015)
126 Donofrio et al (2020)
127 GoC (2020)
128 e.g., Kim et al (2016)
129 Land et al (2016)
130 ibid
131 ibid
132 Olewiler (2004)
133 Brander et al (2013)
134 Brander et al (2013)
135 Riley (1994)
136 e.g., Moudrak et al (2017)
137 COSEWIC (2012; 2016)
138 e.g., Elk River Guiding Company (2021)
139 MFLNROR (2021)
140 BCFW (2021)
141 BCMFLNR (2015)
142 ibid
143 GFW (2021)
144 SoilGrid (2021)
145 NFI (2021)
146 Kurz et al (2013)
147 Shaw et al (2005)
148 Values from Canfor (private data) and Natural Resources Canada (2021)
149 GoC (2020)
150 Canfor (2017)
151 Collison (2021)
152 Collison (2021)
153 Area values from Collison (2021); estimated volume derived from private Canfor data.
154 MFLNRO (2016)
155 Collison (2021); government data at DataBC (2021)
156 This is based on a personal conversation with MBCA management
157 Petryshen (2020)
158 Living Carbon Investments et al (2014)
159 ibid
160 GoBC (n.d.)
161 Ogle et al (2019)
162 Daryanto et al (2018); ICC (2021)
163 Mahal et al (2019)
164 PEIAF (2003)
165 AAFC (n.d.)
166 Wall et al (2002)
167 PEIAF (2021)

168 PEIFA (2019)
169 Carter et al, 1998
170 GoC (2020)
171 Nyiraneza et al (2020)
172 Statistics Canada (2021)
173 SoilGrids (2021)
174 NFI (2021)
175 GFW (2021)
176 Drever et al (2021)
177 See Pearce and Moran (1994) for a methodological overview
178 These range from back-of-the-envelope calculations like Anielski et al (2005) to a careful study using interviews in the Lutsel K'é community by SVA Consulting (2016)
179 Wilkinson (2013)
180 Wilkinson (2013)
181 ibid
182 The Outspan Group Inc. (2011)
183 Data from ibid
184 ibid
185 ibid
186 Since the input-output multipliers were calculated in 2017, we converted to 2017 dollars.
187 Data from the Outspan Group Inc. (2011)
188 Quoted in Wilkinson (2013)
189 SVA Consulting (2016)

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