ECOLOGICAL FOOTPRINT INITIATIVE | YORK UNIVERSITY

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Measuring and managing Canada's use of the Earth's regenerative carrying capacity

SYNTHESIS REPORT

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In April 2018 a new international partnership began as a joint effort between the non-profit Global Footprint Network and York University. Learn more about the York Footprint Initiative (https://footprint.info.yorku.ca).

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Background

Ecological Footprint and Biocapacity (EFB) are integrative measures of the demand for the Earth's carrying capacity and its supply. These measures can be applied at multiple spatial scales and can be compared over time and across jurisdictions. Biocapacity measures the capacity of lands and waters to sustain humans with renewable resources such as food and fibres and forest products, to sequester anthropogenic carbon emissions, and to accommodate built settlements. This capacity is comparable to demand, measured as Ecological Footprint, with its additive components of cropland, grazing land, fishing grounds, lands used by built-up infrastructure, and forested lands providing forest products or sequestering carbon.

The conceptual approach was pioneered in Canada over 25 years ago (Wackernagel, 1994) and has been continually improved and applied in a diversity of settings from the national level (Lin, Hanscom, Murthy, et al., 2018) to local municipalities (Isman et al., 2018). The EFB has demonstrated exceptional relevance across sectors and socio-political groups regardless of political or cultural sustainability practices. As a result, it is now used widely across the world to support sustainability assessments, but still with relatively little uptake in Canada.

This research project aims to further understand the demand for knowledge regarding Canada's use of the Earth's regenerative capacity through the EFB framework. Among Canadian policymakers informed about the concept and measures, those at a sub-national level have raised questions about sub-national data use from EFB national accounts. Canadian policymakers have raised questions about the relevance and substitutability of nationally- versus internationally sourced input data at the national level. Meanwhile, academic and global use of the EFB continues to increase, demonstrating sustained applicability and broad demand for the continued collection and dissemination of the data. For these reasons, we conducted this knowledge synthesis and knowledge mobilization project on topics relating to better and more accurate EFB accounts and to understand how civil society and governments of all levels measure Canadians' use – and dependence upon - the Earth's carrying capacity. Collectively, with stakeholders, we have developed an integrative research agenda for the future of the EFB.

Objectives

This project is broken down through three objectives to ascertain what information is currently available to the public and academic audiences, if this availability meets required needs, and to test the certainty of the data available for use.

Objective 1: Synthesize the knowledge of measurement of human use of carrying capacity generated by research on Ecological Footprint or the National Footprint Accounts.

Objective 2: Synthesize the demand for knowledge required in managing human use of carrying capacity by relevant Canadian actors, including academics, policymakers, NGO leaders, and other sustainability workers.

Objective 3: Evaluate the sensitivity of the National Ecological Footprint Accounts to differences in input data, in order to understand the empirical significance of key parameters that have been questioned by researchers and policy professionals.

Results

The literature review demonstrated consistent growth in global academic demand and use of the EFB in environmental and agricultural sciences, primarily using the tool for specific problem contexts and innovations on the methodology. The EFB criticisms make up 15% of published articles, with primary concerns regarding aggregation, scale, false concreteness, energy centrism, anthropocentrism, yield factors, and data quality. The Global Footprint Network published responses to some of the criticisms in response to this literature review.

While the literature review demonstrates Canadian academics as among the top users of the accounts, the interviews demonstrated a continued lack of uptake among Canadian policymakers at all levels. Both the literature review and the interviews suggest the need for more publicly accessible materials to more easily explain the accounts and the need to develop easily applicable methodologies for policymakers at various scales. The interviews also demonstrate the need for biocapacity accounting at the provincial scale to better understand Canada's natural capital instead of relying on best estimates. Empirical data is required to ensure Canada remains rich in natural resources and wild spaces. The interviews also point to a greater need for disaggregated data for municipal policy development and campaigns that help drive individual behaviour change.

While the literature review is thoroughly comprehensive, the interviews include only a small sample size of relevant Canadian actors. We did not try to expand the coverage of stakeholders as the interviews quickly uncovered a great need for accessible information to provide greater clarity on the opportunities and limitations of EFB for policymakers. Our next immediate step is to develop a toolkit in response to this limitation, share it widely, and conduct focus groups with more stakeholders to expand collaborations and better inform the research agenda.

Implications

This work has strengthened and reignited collaborations between the EFB research groups, provincial actors across Canada, sustainability NGOs, and think thanks all with an interest in developing provincial and municipal data accounting for better policy. This network has already begun the co-development of a research agenda between policymakers, NGOs, Indigenous communities, and academic groups including a) continued development of the national accounts, b) disaggregated data for municipal decision making on locally relevant issues such as

infrastructure and recreation, c) provincial biocapacity accounting for a deeper understanding of natural capital, and d) behaviour change campaigns for individual and household levels.

Conclusion

This research related to the knowledge synthesis grants demonstrates the continued relevance of the EFB in both academic and public settings. Outcomes of the research have sketched out a future research agenda for the EFB to establish stronger metrics and approaches to measure and manage Canada's use of the Earth's regenerative carrying capacity.

About the Ecological Footprint and Biocapacity

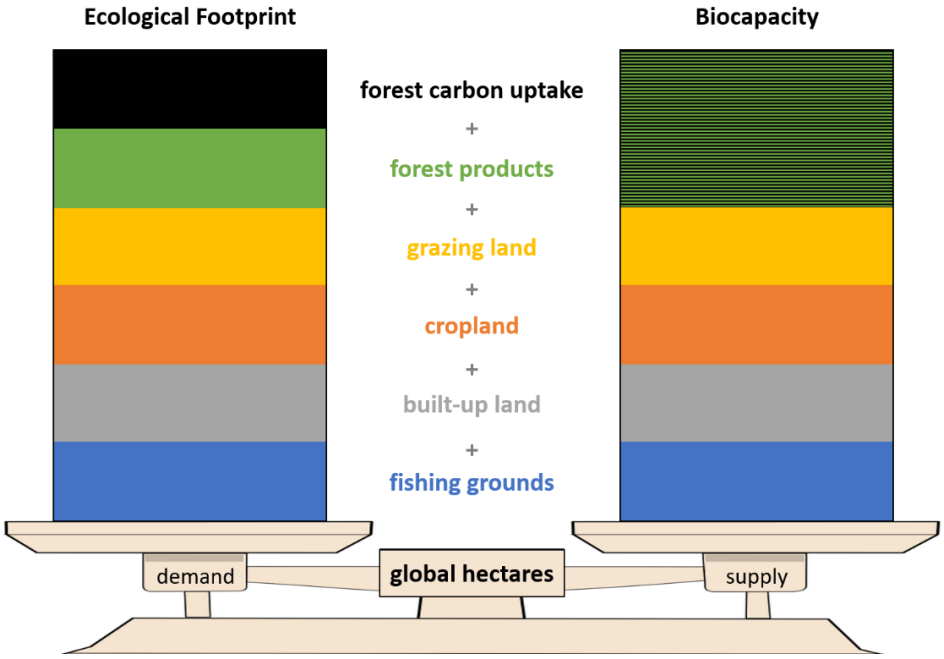

Figure 1: The framework of Ecological Footprint compared to Biocapacity

Ecological Footprint accounting measures the demand on and supply of nature.

On the demand side, the Ecological Footprint adds up all the productive areas for which a population, a person or a product competes. It measures the ecological assets that a given population or product requires to produce the natural resources it consumes and absorb its waste, especially carbon emissions.

On the supply side, a city, state or nation's biocapacity represents the productivity of its ecological assets (including cropland, grazing land, forest land, fishing grounds, and built-up land). These areas, especially if left unharvested, can also absorb the waste we generate, especially our carbon emissions from burning fossil fuels.

CONTEXT

Humanity faces many environmental challenges, including the conservation of biodiversity, the need for a dramatic reduction of greenhouse gas emissions, and meeting the United Nations Sustainable Development Goals in a world of 7.8 billion people, rising to 8.5 billion by 2030. To best manage these challenges, humanity needs to understand the Earth's carrying capacity to appropriately manage human-nature interactions.

Given that ecosystem capacity to sustain human life is a function of human demands, we regard carrying capacity as the amount of productive and absorptive flows from ecosystems that can be regenerated to sustain humans and other species. Humanity's demands on carrying capacity are increasing, with a growing population and increased demand for climate solutions that do not interfere with perceived progress. To best develop informed public policy, practice, and research agendas, a systemic, science-based, ongoing, quantitative assessment of Canada's use of the Earth's carrying capacity is needed.

Currently there are no governmental measures of the "carrying capacity" of the lands and waters in Canada at a Federal or Provincial or Territorial level. The closest national measures are an inventory of land cover, timber stocks, and the reserves of select minerals and fossil fuels, measured in physical and monetary units. Neither units infer sustainable rates of use.

The word "capital" is often used to describe the capacity of entities to provide flows of benefits over time. Capital is applied to labour (human capital), machinery and buildings (produced capital), finance (financial capital), and ideas (intellectual capital). Metrics about the "capacity utilization rate" are published by Statistics Canada to refer to the proportion of produced capital that are being used at a moment in time; rates of unemployment and labour force participation characterize the utilization of human capital. The concept of "natural capital" is increasingly being applied to nature, to characterize the stock of renewable and non-renewable resources and the ecosystems that provide flows of "ecosystem services". Statistics Canada quantifies and monetary values the quantity of natural resource reserves in Canada and some provincial governments have measured the capacity of lands and waters to provide ecosystem services. Even here, the capacity of natural capital is measured in monetary units.

There are various economic rationales for moving beyond natural capital's monetary valuation as a cross-scale comparative measurement. Monetary values previously used to measure natural capital depletion are misleading and indifferent to crucial biophysical realities, not least because monetary and economic growth seems infinite within a finite biophysical system. Monetary value fluctuates with world markets, which alone sets this as an insufficient standard for long-term comparison. Perhaps more importantly, money is not necessarily associated with material wealth or improved well-being (Henderson, 2012; Rice, 2008). Biophysical scarcity is

not reflected in market prices (Hall et al., 2001), rather the perceived scarcity based on the market. Market prices are influenced by various social conditions such as competition, demand, and transaction costs while also incorporating future discounting, making natural assets appear less valuable further into the future. Long heralded as an appropriate measurement of natural assets, prices are an unreliable way to measure natural capital.

There are also psychological reasons to remove money from valuation. For example, such an approach perpetuates long-standing colonial and growth-oriented dualistic separations of humans from nature. This dualism has long underscored the Global North's approach to natural conservation, reservation, and restoration. The "abstract wild" is something to be paid for or experienced, not lived within and among. Natural services essential for life versus material objects are priced equivalently, instead of recognizing one may have additional unseen value that cannot be compensated. However, quantitative metrics are the most reliable and convincing form of knowledge for widespread environmental policy making, and thus measuring natural capital is important beyond monetary valuation. While these social issues spark some resistance from ecological scholars in relation to quantifying nature by any means, natural capital accounting can help provide a clear picture of how well environmental policy works overtime without monetary association.

Ecological Footprint and Biocapacity accounting involves applying a system of parameters and equations and procedures to economic, social, and environmental statistics in order to quantify the capacity of lands and waters to provide humans with a sustained flow of food, fibres, wood products, areas for settlements, and the sequestration of anthropogenic carbon emissions. This accounting has been routinely applied on a national basis to produce the National Ecological Footprint and Biocapacity Accounts. The 2021 edition of these national accounts were released in the fall of 2020 by researchers at York University, in partnership with the Global Footprint Network which publishes the data on its open-access data platform data.footprintnetwork.org. Global results show a steady increase in Ecological Footprint over time, surpassing global carrying capacity on an annual basis since 1970 (Figure 2).

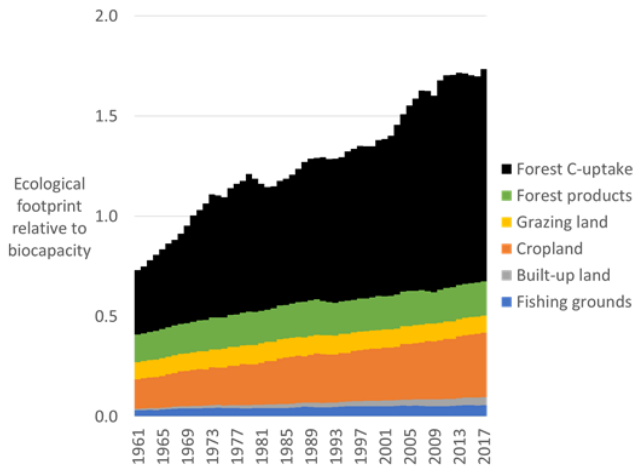

Figure 2: Global Ecological Footprint has grown over time

Figure 3 shows how the accounts are calculated. The EF is calculated by dividing harvests and emissions by national yields of resources. The result is multiplied by a Yield Factor (YF) and a Global Equivalence Factor (EQF) to generate units of global hectares from national hectares. Biocapacity is calculated by multiplying the productive carrying capacity supplied by planetary capacity supplied of each resource's YF and EQF. An Intertemporal Yield Factor IYF is also applied to the cropland YF. Results provide an overall view of the biologically

productive area necessary for humans at all scales - global, national, regional, and individual. It is intentionally framed as an accounting system rather than as a normative indicator for development to maintain broad applicability (Lin, Hanscom, Martindill, et al., 2018; Lin, Hanscom, Murthy, et al., 2018). Ecological Footprint and Biocapacity are the sum of components that specify the demand for (or supply of) fishing grounds, built-up land, cropland, grazing land, the area of built-up land used for settlements and infrastructure, and the area of forests providing forest products or sequestering anthropogenic carbon (beyond the amount sequestered by global oceans).

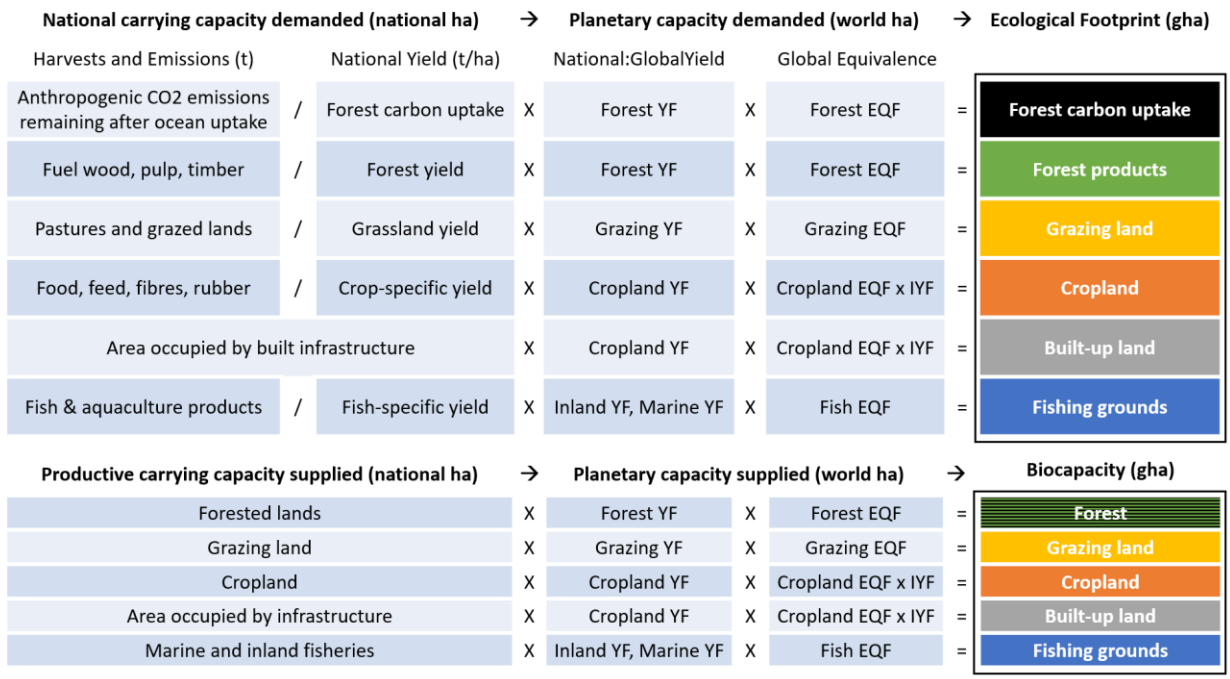

Figure 3: The components and logic of the Ecological Footprint and Biocapacity accounts.

The EF can be calculated for any activity with a defined boundary such as activities, institutions, individuals, and populations of all global, national, or regional scales. The EFB measures any population's demand for carrying capacity in units and compares this to the Biocapacity of any portion of the planet. The approach quantifies Biocapacity as the carrying capacity of lands and waters in terms of their potential to supply food and fibres, forest products, areas for human settlements and infrastructure, and their capacity to biologically sequester anthropogenic carbon emissions (Lin, Hanscom, Martindill, et al., 2018). Biocapacity is therefore, the supply of regenerative capacity of each of the natural components. They are measured in global hectares, a unit that allows for comparisons across the planet and changes overtime.

Uptake Statistics

- data.footprintnetwork.org saw an average of 200 000+ unique visitors per year in 2017-19
- The public data package had over 5000 downloads per year in 2016-19
- Multiple other hosts of the data including Work Resources Institution, Biodiversity Indicators Partnership, data.world, and others
- Personal ecological footprint calculator sees 2 million+ unique visitors per year
- Earth Overshoot Day has had 4 billion media impressions from over 5000 websites in 112 countries, 8 online partnered events

The EFB databases provide the most integrative metrics for measuring the demand and supply of carrying capacity at multiple spatial levels and degrees of detail. The approach was pioneered in Canada over 25 years ago (Wackernagel, 1994) and has been continually improved and applied at various spatial scales (Lin, Hanscom, Murthy, et al., 2018) and municipally in Canada (Isman et al., 2018). The EFB has demonstrated exceptional relevance across sectors and socio-political groups regardless of political or cultural sustainability practices. As a result, it is now used widely across the world in support of sustainability assessments.

For example, Slovenia included the National Footprint Accounts in their National Development Strategy for 2030, in which they use the EF and Biocapacity as leading indicators with a target of 20% decrease. In Portugal, 18 cities signed on to a three-year EF project with the goals of a) assessing the EF and Biocapacity of each city, b) engaging with citizens and stakeholders regarding the EF, and c) studying policies to promote sustainable land use management.

The EFB is currently central in the national planning documents for over 13 countries and has been applied to at least 300 subnational calculations, based on the knowledge of the research group.

The concept and measures of EFB have also enjoyed tremendous public uptake. The term “footprint” is now synonymous with human impact. Each year, millions worldwide calculate their ecological footprint using a web-based calculator provided by Global Footprint Network. The Global Footprint Network uses “Earth Overshoot Day” as a campaign to help people visualize and understand the implications of an unequal balance between available biocapacity and human resource use.

In 2020, Earth Overshoot Day was on August 22nd, meaning that all available resources and biocapacity available for human life was used by this date. Humans used more than the Earth produced for the remainder of the year, inching closer to ecological bankruptcy. In other words, by August 22nd, humanity used all of the regenerative resources for 2020, so that as of August 23rd, humanity consumes more resources than the planet can regenerate in a year. Earth Overshoot Day has generally been occurring earlier each year (August 1st in 2018 and July 29th in 2019). It is thought that this is mainly due to carbon dioxide emissions, so the carbon Footprint. 2020’s Overshoot Day presumably occurred later due to the global pandemic.

It is also possible to discern a single country's Earth Overshoot Day. At a national level, a country's overshoot day is the day of the year in which Overshoot Day would fall if humanity consumed like those in the country. A country's overshoot day is calculated by using the most recent yearly data from the National Footprint Accounts, although there is a slight time delay as 2019 is based on 2016 data. Canada's Ecological Footprint was 7.7 global hectares (gha) per person with a global biocapacity of 1.63 gha per person, and thus if everyone lived like a Canadian, it would take 4.72 Earths to sustain life. To then calculate Canada's overshoot day: 365 * (1.63/7.7) results on the 77th day, or March 18th. In comparison, Costa Rica's overshoot day is August 10th.

The national data is currently available for public access as a time series from 1961 to the present. The data is available on various sites, including the Footprint Network's data site. With this data, users can see different country trends, analyze data by land types, or compare the footprint per capita between different countries. On this site, the data is also set against the Human Development Index to compare the EFB to levels of human development. Furthermore, the EFB of a jurisdiction can be measured on a trade-adjusted basis to identify the Biocapacity used to support imports and exports. Such a measurement is especially useful for Canada, considering high trade levels with the rest of the World. With this data, individuals can compare the demand and supply of regenerative capacity.

The EF of humanity has vastly increased since the 1960s. Another way to view this is the relative biocapacity (Figure 4). The National Footprint Accounts uses the EF to provide annual accounts of biocapacity and the EF for the world and all countries. As part of this knowledge synthesis project, the research team at York University produced the 2021 accounts, including recalculation of the entire EF timeline with new data and parameters and extension of the data to the latest full data year of 2017. This process enhances available data and incorporates more data reported for a greater number of countries with higher data quality scores. The update also includes more fish species counted as harvests and as traded commodities and more complete data that links to fishing grounds.

The EFB is also used for research and policy related to sustainable tourism, sustainable diets, teaching and practice of sustainability in higher education, biodiversity and country risk assessments, country competitiveness, as a comparative tool for demographically sorted subpopulations, and trade dependencies. At municipal, provincial, regional, and national levels, global governments have applied the metric in various ways. Furthermore, researchers

continue to use the approach and publish books and scholarly journal articles that demonstrate novel applications and address methodological challenges and opportunities.

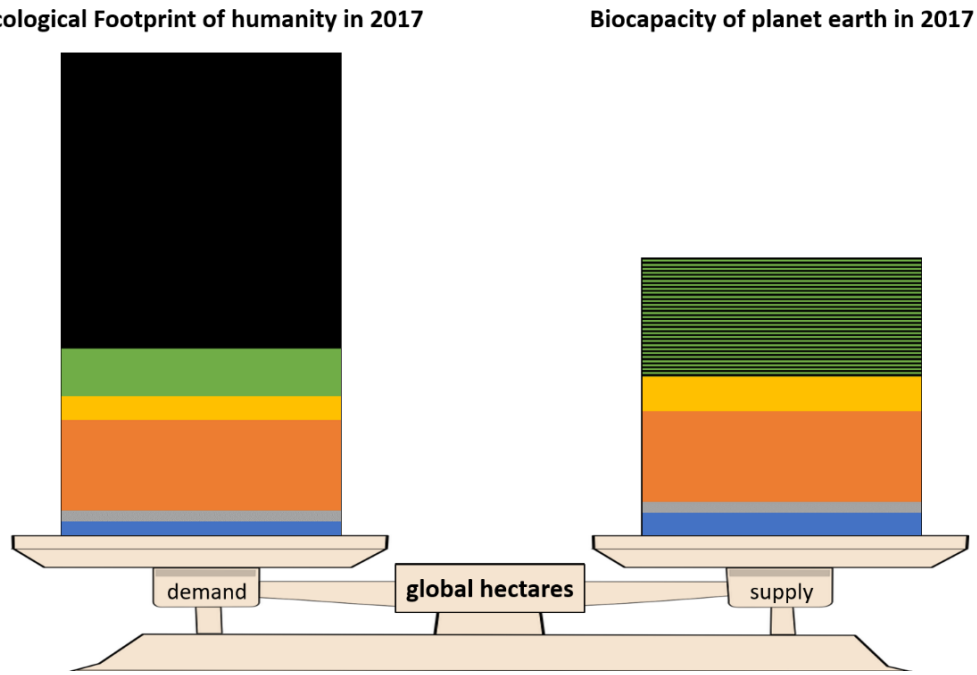

Figure 4: The Ecological Footprint of humanity compared against global biocapacity.

The purpose of this research project is to further understand the demand for knowledge regarding Canada's use of the Earth's regenerative capacity. A knowledge synthesis of this nature is used to bridge the gap between future research agendas and decision making. Among Canadian policymakers informed about the concept and measures, those at a sub-national level have raised questions about sub-national data use from national accounts. At the national level, Canadian policymakers have raised questions about the relevance and substitutability of nationally-versus internationally sourced input data. Meanwhile, governmental organizations and civil society leaders have yet to incorporate metrics and measurement systems to inform decisions and future scenarios. For these reasons, we conducted this knowledge synthesis and knowledge mobilization project on topics relating to the Ecological Footprint and Biocapacity to inform civil society and governments of all levels about measuring Canadians' use – and dependence upon - the Earth's carrying capacity (Figure 5).

With this SSHRC Knowledge Synthesis Grant, we evaluate key metrics and measurement systems used to quantify terrestrial and aquatic systems' capacity to sustain humans with regenerative goods and services if humans do not consume them at a rate that is above their renewal rate. Our assessment considers the strengths and limitations of metrics applied at various jurisdictional scales, considering that the management of lands and waters is affected by the policies and plans of all government levels in Canada. We synthesize and mobilize current knowledge that could inform civil society and governments of all levels about how Canadians use – and depend upon - the Earth's carrying capacity. Additionally, this study

evaluates the sensitivity of data sets currently used in the National Footprint Accounts by looking at how changes in parameters alter aggregate Footprint results at different levels. We will compare current data sets extracted from international sources against Canadian data sets to understand whether our data source could have a significant impact on our results.

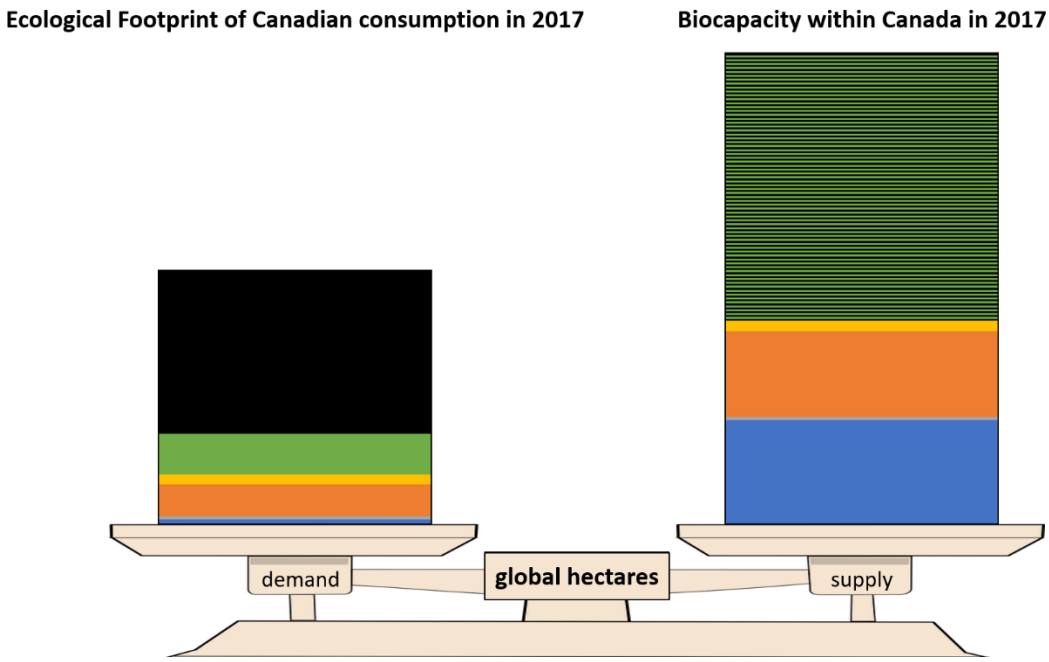

Figure 5: Canada's Ecological Footprint of consumption compared with biocapacity generated in Canada. Despite having one of the highest per-capita average global footprints, Canada supplies more global Biocapacity than it uses.

OBJECTIVES

Objective 1: Synthesize the knowledge of measurement of human use of carrying capacity generated by research on Ecological Footprint or the National Footprint Accounts.

Objective 2: Synthesize the demand for knowledge required in managing human use of carrying capacity by relevant Canadian actors, including academics, policymakers, NGO leaders, and other sustainability workers.

Objective 3: Evaluate the sensitivity of the National Ecological Footprint Accounts to differences in input data, in order to understand the empirical significance of key parameters that have been questioned by researchers and policy professionals.

APPROACH AND METHODOLOGY

The Ecological Footprint methodology incorporates demand and supply-side uses of biologically productive land and ecological assets in a country, respectively. It expresses these as a standardized unit of global hectares. The EF does not incorporate social ideals or goals for well-being, such as justice and power issues. However, the EF can be used in policymaking to complement other measures that more clearly relate to social and relational elements. The following methods have nothing to do with the Footprint itself but rather with an approach to ascertain the use, dynamics, and demand for the Footprint with relevant Canadian actors. A thin cognitive line exists between the public need for a social tool and the EF as an ecological tool. The methods were chosen to incorporate social demands alongside what the EF offers.

Different methods were employed to meet the three different objectives. This section includes three distinct sections that include methods for each of the three objectives. Research conducted to meet each objective operates around the same problem definition: to establish a future research agenda for the EFB by determining the quality of the data and how the concept is understood, used, and needed in academia and the Canadian public. Our motivation emerges from the need to a) mobilize knowledge within our internal academic community regarding the variety of uses and needs for broader use of the EF, b) develop a plan of implementation for the EF across Canada at different scales and c) bring academic and public use demands together to develop a research agenda for the EFB accounts at York University.

Given the EFB tool and data set's size and nature, we incorporated different research scales across the project with specific and intentional boundary definitions. For objective one, our primary boundary was the use of “ecological footprint” in research papers worldwide. This provides a broad overview of how researchers use the EFB, where it is most used, and how use has changed over time. We narrowed our boundary for objective two by focusing on the Canadian demand of the EFB by environmental stakeholders with varying interests and perspectives. Finally, for our third objective, we dealt strictly with the available EFB data to see the kinds of information that can be extracted and how the data can be improved. These physical boundaries ensured focused research to meet the objectives of the project.

We conducted a systemic and quantitative literature review and performed a sensitivity analysis on the EFB data for a general and overall understanding of the state of the research. These approaches produced less biased and quantitative outcomes. We coded the literature review literature review using a thorough content analysis approach, interviewed stakeholders, and conducted affinity sorting of central themes for inclusion of social-cognitive data. These approaches complement produce complementary knowledge to compare qualitative and quantitative outcomes of the objectives for more complete views and outcomes.

Methodology for Objective 1

To synthesize the supply of knowledge regarding the measurement of human use of carrying capacity, we conducted a systemic literature review of research papers related to the EFB. We searched for all papers using the term “ecological footprint” from 1994 – 2020 through Scopus. After selecting the papers, researchers individually assessed each paper according to a rubric followed by a second research review and a reconciliation meeting between the two coders to develop the final assessment. Additionally, we compiled the sources into a shared Zotero collection, with ~60 items regarding critiques since 1998. These sources were found and accessed via Google Scholar using the search <<critiques “ecological footprint” methodologies data>> for articles, excluding patents and citations from any time, which resulted in 16100 results.

Methodology for Objective 2

To synthesis the demand for knowledge use in managing human use of carrying capacity by relevant Canadian actors, we conducted interviews with key stakeholders. Stakeholders were chosen based on three criteria:

1. A Canadian based sustainability stakeholder (government worker, NGO leaders, and civil society leaders)
2. Equal geographical representation across Canada
3. Equal representation from different kinds of stakeholder groups (government representatives, NGO workers, civil society leaders)

We also utilized and prioritized groups involved with the early planning of the Ecological Footprint Initiative at York University. After obtaining relevant ethics clearance, we conducted online interviews, approximately 30 minutes in length, using open-ended interview questions. The interview questions were broad as they act as a prime to ignite the subject's imagination, mainly to set up opinions on professional goals and curiosity of how the EFB could benefit their organization's sustainability agenda or work. This imaginative element is uncodified and uncovers taken-for-granted assumptions about things such as the EFB tool. EFB research associate Kaitlin Kish and data analyst Mark Milnes conducted all the interviews. Dr. Kish led the interviews while Milnes provided expert views and clarification on technical details of the EFB. Interviews are recorded and stored on a private off-line private hard drive, transcribed, coded based on main research questions, and affinity sorted. The interviews are a crucial component for understanding public demand for the EFB and thus future research directions.

Methodology for Objective 3

To conduct a sensitivity analysis of the National Ecological Footprint accounts, we employed students previously trained in sustainability informatics to perform a sensitivity analysis on variations to the input data and parameters. A sensitivity analysis provides insights into the sensitivity and data structure of the accounts. The sensitivity analysis compares internationally

sourced data (currently used in the National Footprint Accounts) against Nationally sourced Canadian data. This analysis consisted of two stages: 1) finding alternative data sets to compare how sensitive they are compared to our current working data sets; 2) sourcing alternative data sets from Canada, to compare against the same data reporting by international institutions.

Several Canadian data reporting bodies were consulted, including Statistics Canada, Natural Resources Canada and Agriculture and Agri-Food Canada. We searched for data related to forest products and cropland products. Data sets needed to be comparable to our current working data sets in terms of metrics, categorization and number of listed products. We also evaluated the sensitivity of the accounts to random differences in the Equivalence Factor (EQF) and Ocean Uptake and Net Annual Increment (NAI).

We expected a large degree of similarities between data sets. In anticipation of unavailable or identical data sets, we assumed that the sensitivity analysis would be limited to a subset of the accounts, with our results documenting why data was not available and the implications this may have in terms of future research and production of the National Footprint Accounts.

Overall Analysis

We analyzed and synthesized the data collected for the three objectives by integrating the data. In this knowledge assemblage phase, the data and information gathered throughout the various elements were standardized into a single framework for understanding them collectively. The research question was developed at a collaborative meeting between the Global Footprint Network, York University, Statistics Canada, and the Canadian Society for Ecological Economics. The first analytical stage is to map out and identify key elements of the research paradigm that are important later during synthesis. To gain an appreciation of the Ecological Footprint's prevailing opinions and research trajectory, a multidisciplinary research team conducted the systemic literature review (objective 1) and conducted a sensitivity analysis of the accounts (objective 3). We identified key stakeholders and actors related to the method to determine the demand for the footprint and frame a future research agenda (objective 2).

RESULTS AND KEY FINDINGS

In this section, we report on each objective's results and the key findings of the research.

Objective 1: Literature Review

Researchers analyzed 250 papers on the topic of the Ecological Footprint from 1992-2019 as the last full year when we started to sample the literature. Annual publications have grown over time, with a notable peak in 2013 followed by a rebound with the most new publications in 2020 (Figure 4). Most papers considered the standard six EF components and followed the conceptual approach promoted by the Global Footprint Network. Half of the papers used the data from the Global Footprint Network or the National Footprint Accounts, while the others obtained the data from elsewhere. We can assume that continued updates to the accounts will result in continued growth of use in academic literature and studies, but the location of stored data is less important. 4.6% of the papers had no mention of biocapacity, while 67.6% used all standard components of biocapacity, and the rest used just a single indicator (e.g., fisheries). Countries with some of the highest publication rates of EFB are Canada, China, and Spain. The high Canadian usage is expected, given that the tool was developed at the University of British Columbia and had a high profile across the country.

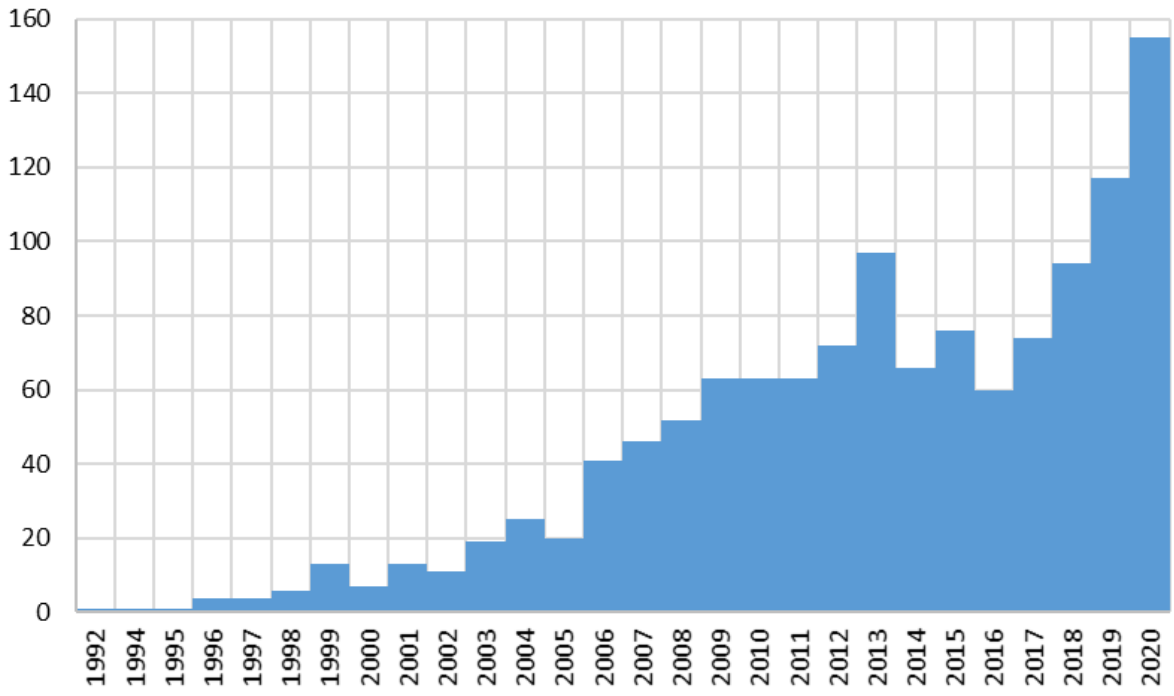

Figure 6: Number of new English EFB-related peer-reviewed publications indexed in Scopus per year

The literature review demonstrates broad international usage of the tool in application across sectors including industry, NGOs, businesses, governments, households, and individuals. Primary usage appears in the environmental and agricultural sciences, followed by economics and decision sciences (Figure 5).

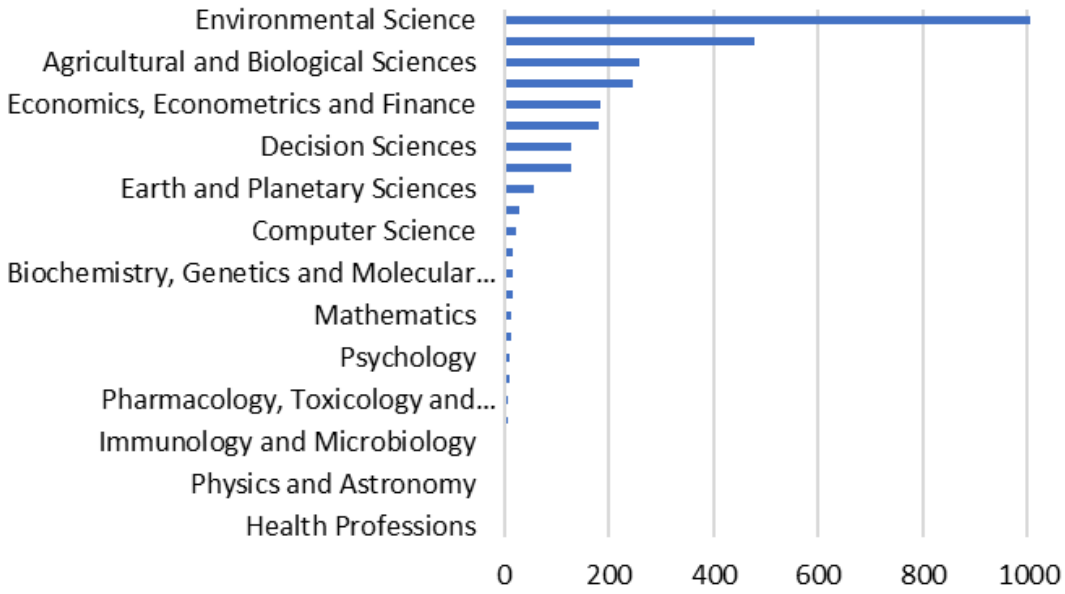

Figure 7: Disciplinary categories of EF publications

Most of the papers use the Global Footprint Network data with more attention given to the footprint rather than biocapacity. While over 80% of the publications focused on innovations or uses of the Ecological Footprint and only 15% engaged with criticism and debate, there is extra attention given to the criticisms of the tool as these provide the best overview for areas of opportunity. While questions remain regarding the dataset's global consistency, the Global Footprint Network's accounting system is "the most comprehensive assessment of the ecological status of nations available" (Rees & Wackernagel, 2013, pp. 1–2). However, among a small selection of academics, the utility of the Footprint for decision making is subject to ongoing criticism (Bastianoni et al., 2012; Fiala, 2008; Giampietro & Saltelli, 2014; van den Bergh & Verbruggen, 1999) and debate (Blomqvist et al., 2013b, 2013a; Galli et al., 2016; Rees & Wackernagel, 2013). Major critiques of the method (Thornbush, 2020, p. 12) revolve around issues of:

- Aggregation (Giampietro & Saltelli, 2014);
- Spatial and temporal scale (Fiala, 2008; Lenzen et al., 2007; van den Bergh & Verbruggen, 1999);
- False concreteness (Van den Bergh & Grazi, 2014; van den Bergh & Verbruggen, 1999);
- Utility and anthropocentrism (Venetoulis & Talberth, 2008);
- Quality (Fiala, 2008; van den Bergh & Verbruggen, 1999);
- Land-use (Kitzes et al., 2009; McManus & Haughton, 2006);

- Energy-centrism (Blomqvist et al., 2013a; McManus & Haughton, 2006);
- Equivalence factors (Kitzes et al., 2009; Monfreda et al., 2004; van Vuuren & Smeets, 2000);
- Yield factors (Monfreda et al., 2004; van Vuuren & Smeets, 2000) and;
- Data quality (Monfreda et al., 2004; Venetoulis & Talberth, 2008).

Key Takeaways

1. Use of the EFB continues to grow in academia, particularly in the use and innovation of the tool.
2. Researchers who use the EFB come from all over the world with some geographical concentration in China, Canada, and Spain.
3. There is use of artificial intelligence in EFB related data analysis and decision making.
4. The review identified the use of EFB for system design of future sustainability as a main area for future research.

Objective 2: Knowledge Demand Interviews

We held a multi-stakeholder meeting and 18 interviews with key decision-makers, policy experts, and sustainability advocates from Canadian environmental NGOs, charities, think tanks, and across all levels of government. The multi-stakeholder meeting was held over two days in Toronto, ON, and the 20-60 minute interviews took place online. The most significant outcome of these discussions is a high demand for measures and accounts to inform environmental decision-making, such as Ecological Footprint. Demand primarily points to the need for disaggregated granular data at the municipal level and biocapacity accounting at a provincial level to inform policy and have a deeper understanding and appreciation for natural reserves across Canada. Participants argued that the monetary valuation of these stocks is required to make conservation arguments.

Some groups argue that empirical data regarding these stocks would help bolster Canada's identity as a country rich in natural spaces. The biggest argument against such approaches is that they create a dualism between humans and nature by placing an anthropocentric valuation on natural spaces rather than value in their own right. However, the interviews suggest that empirical, numeric, and monetary valuation of natural stocks would help shift away from historical efforts to create an abstract wild or frontier conservationism by giving a concrete understanding of Canada's natural spaces. This helps to deepen the relationship between human and natural spaces. Without such accounting systems over time, there may be a tendency to believe that Canada has significant nature reserves, and thus there is less worry about overshooting carrying capacity. However, humans tend to miscalculate and misunderstand values and stocks without clear empirical interpretations.

Members of the NGO community say that their main goal is to deliver information to the public to help create and inform policy and individual behaviour. They all said the EFB accounting

could help here, but there needs to be more regionally specific data such as provincial and municipal data. There is broad recognition that Canada has vast wild spaces, and the primary approach has focused on imagery of this to appeal to emotions. However, yearly accounting to demonstrate that there is stress on natural spaces would be highly effective in campaigns.

Stakeholders also indicated that academia is the most trusted source for data, with the caveat that some academics do not adhere to ethical practices regarding community engagement. Some academics conduct research within a community, extract knowledge, and give nothing back, which is increasingly disfavoured. This problem is so ubiquitous that it is now often dealt with through the ethics process to ensure researchers do not take advantage of communities. Community groups, especially Indigenous participants, further suggested an academic partnership with an NGO would be beneficial as that covers both intellectual and emotional trust. Additionally, non-experts felt they and their organizations lack the specialty to disseminate and use the Footprint and Biocapacity.

The remainder of the outcomes are sorted into three categories: policy needs, research questions, and discussions of culture and complexity concerning the tool.

Policy needs

The most significant demand from stakeholders regarding the EFB is data related to natural capital and monetary valuation of ecosystem services. There is a strong call for clear and accessible data at a provincial level that takes stock of natural capital across provinces. Policymakers and NGOs require this data to see how changes happen over time, particularly concerning implementing different policies and comparing to other provinces. Three participants said it is problematic that there is no exact way to demonstrate if provincial governments are doing a good job of protecting natural spaces. There are some regionally specific data, but the lack of data regarding what natural capital exists makes it exceedingly difficult to write clear policy briefs. The research project focused specifically on what municipal governments demand researchers and NGOs to apply to their priorities area for decisions informed by EFB (Image 6).

At a municipal level, government representatives want to include the footprint in the tenure bidding process. For example, there are lower and higher footprint buses, but the municipality is primarily concerned about which one costs more, over a certain period. Thus, there is a strong demand for a tool to understand how these precise decisions relate to the environment. Money spent needs to save money ultimately, and if it also has demonstratable benefits for the environment, then there is a strong case for what may potentially be the second-best monetary option. Even in cases where monetary valuation was not important to the culture or group, they recognized the importance of monetary valuation as the most effective way to connect with government policymakers. However, there is a recognition that nature's monetary valuation is difficult to support because of how quickly it can meet all the same issues seen with

any stock. Thus, there is a question regarding how wealth in environmental stocks will help the global environment overall. Others mentioned that it would be beneficial to see the cost of inaction.

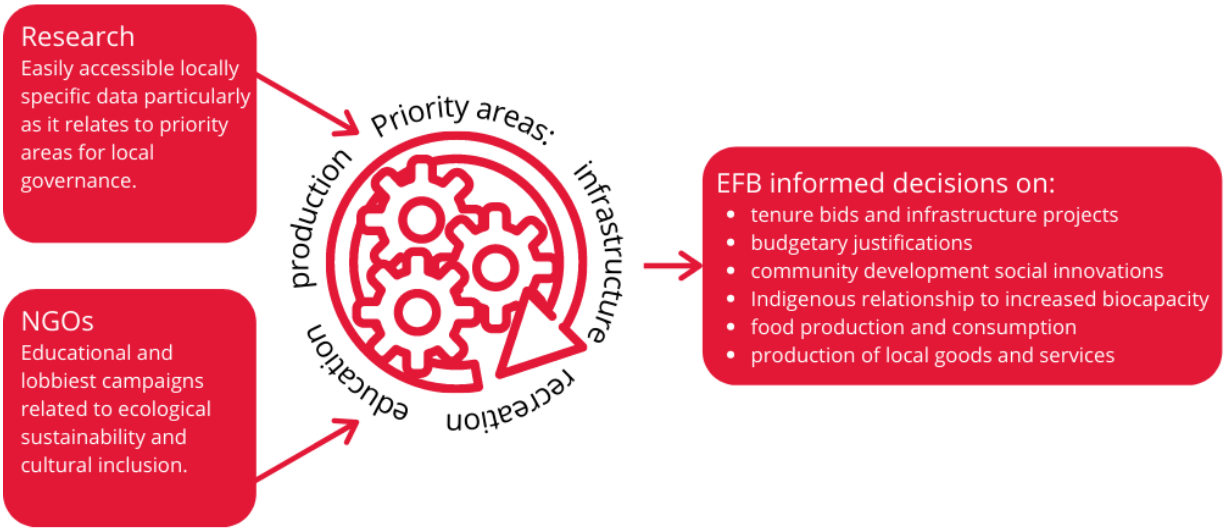

Figure 8: Municipal government demands for policy that incorporates EFB and carrying capacity.

A significant barrier to implementing and using the EFB within specific organizations or with policymakers is the ease of use and perceived need to hire a specific data analyst to use the tool meaningfully. It is not currently easy enough for anyone below a federal level to extract relevant policy development information, since the public data is provided on a national basis. There was a recognition that if the Footprint Initiative were to produce analytical tools, graphs and policy briefs relating to resource use on a provincial level, these would be useful for policy development at both provincial and municipal levels.

A broader research team at York University had the recent experience of generating provincial-level estimates of the Biocapacity of lands and waters within Ontario, and the Ecological Footprint of consumption within Ontario in 2015 as compared to 2010 and 2005. The approach involved apportioning national-level data to categories of final economic demand, using global multi-regional input-output analysis. A resulting Consumption Land Use Matrix disaggregated the national Ecological Footprint components to specific types of consumption at a household level, or consumption by government, or the consumption of materials and energy used for "gross fixed capital formation". The resulting matrix for Canada was then apportioned to Ontario based on its share of national consumption and considering differences in consumer prices and household-level purchases, and the carbon intensity of electricity produced in Ontario. A similar approach could be replicated to other provinces since the relevant data was sourced from Statistics Canada. More challenging would be a pan-Canadian assessment of Biocapacity at a subnational level without provincial-scaled national land inventories that track

changes over time. If this were available, Biocapacity assessments at any sub-provincial level would be relatively easy, such as for municipalities, watersheds, parks, and protected areas.

Municipal participants had requests for future Footprint research and policy development regarding recreation and infrastructure projects. They were interested in whether the FPB could help them decide where to get the most sustainable materials for projects as most of their tax money is spent on infrastructure. Thus, intervention at the infrastructure level is important to make better decisions that ultimately provide larger-scale benefits. They also pointed to the EFB's potential to help in argumentation to prioritize different kinds of recreational activities over others. For example, there was a recent bid for recreational funding in one municipality, and the horticultural club was ranked last out of 15 recreational clubs by the council, citing a perceived lack of community, economic, and environmental benefits. The FPB project could easily produce a toolkit that demonstrates local behaviours and investments that contribute positively to biocapacity and FP reduction, such as horticultural clubs and biking initiatives.

Despite the extensive use of the EFB in Canadian academic literature, there is still a lack of uptake of the tool and methodologies among Canadian policymakers. This may be because a national account of EFP is not helpful in Canada as there are large differentiations from province to province and between municipalities (Kissinger et al., 2013; Moore, 2015). In Vancouver, policymakers are ready and willing to collaborate and explore new approaches to environmental governance, while the municipalities in Southern-Ontario had far greater skepticism and reservations (Moore et al., 2013). Results from the interviews suggest that this is largely because the municipalities spend most of their money on taxes for infrastructure projects, so they need disaggregated granular data for it to be useful. The national level is far too removed to be useful for municipal policy development. Such granular data would also make it possible to compare different cultures and communities more directly. One participant suggested taking such granular data and overlaying that data with a GIS map of settler and Indigenous occupied land.

Research Questions

Research participants from NGOs and various government levels are interested in collaborating with the Footprint Project on future research agendas. Most participants sketch out areas of research they thought would be the most impactful for their work. Many ideas and interests demonstrate that EF researchers need to produce an informative brief that details what the tool can and cannot do.

The themes of monetary valuation and natural capital also came up consistently within this theme, but various other ideas were presented. Most broadly, there is a call for using the EFB in various policy development levels and for generalized policy briefs relating to Canadian

provinces for widescale usage. There is a large gap and need to translate academic and empirical data into useable policy format to influence existing practices.

Municipalities are interested in how the FPB can help demonstrate the benefits of the local production of goods versus imports. Also, on the role of shopping locally for goods and foods. Indicators related to food and consumer behaviour were frequently requested to connect how people eat to a regional account of FPB.

Participants comment that the tool does not seem to be sufficiently valuable for systemic change, given that systemic change comes out of emergent properties, not out of data. One participant said that "someone more clever than me" could "think of unique and interesting alternative data points associated with things such as community development and local production, things that might be non-obvious sustainability indicators." For example, a recent project partnered with the Toronto Regional Conservational Authority looked at how increased mileage of hedgerows drastically enhances local sustainability efforts. This idea came up in discussions with Indigenous participants who asked if the EFB could measure the benefit of a totem pole or a bench in the middle of a forest. While they asked this rhetorically, it relates to the call for unexpected indicators as getting people into nature has long been associated with improved environmental appreciation and awareness.

There was a significant call for using tools, such as the EFB, to help make empirical claims relating to Indigenous reconciliation. For example, one participant asked about the ability to overlay regional biocapacity with Indigenous land ownership to ascertain if Indigenous governance improved biocapacity over time. This is an interesting area for investigation that relates somewhat to a 2014 Supreme Court of Canada decision. This supported the Tsilhqot'in Nation's title over 1,900 square kilometres in British Columbia as part of a landmark decision regarding clear-cut logging permits granted by the British Columbia government without consulting the local Indigenous population living on the affected land. The Supreme Court of Canada's decision in the case of Tsilhqot'in Nation v. The Queen, 2014 SCC 44, reads, in part:

> "The intensity and frequency of the use may vary with the characteristics of the Aboriginal group asserting title and the character of the land over which title is asserted. Here, for example, the land, while extensive, was harsh and was capable of supporting only 100 to 1,000 people. The fact that the Aboriginal group was only about 400 people must be considered in the context of the carrying capacity of the land in determining whether regular use of definite tracts of land is made out."

The historical ruling gives the Tsilhqot'in Nation "the right to use and control the land and to reap the benefits flowing from it." In future research, Indigenous participants are interested to see comparisons between highly colonized areas, federally and internationally, and if communities subjected to more long-term systemic racism and poverty had lower biocapacity

over time. There were various kinds of asks to use the empirical data to demonstrate a correlation between cultural events and environmental degradation.

Finally, research institutes and think tanks were also interested in linking the EFB to social innovation theories. They asked if the footprint itself could be historically placed as a social innovation, and how. They wondered how the data could be linked with other social innovations over time and help measure existing attempts to social innovations in a community. These are immensely broad questions that are essentially asking to link the EFB with social determinants of change and well-being.

Behaviour Change

The most consistent critique is that the tool does not account for cultural behaviour or decisions. As previously mentioned, the tool is not meant to do this, and thus this reiterates the need for more education related to what the EFB can and cannot do. Alternatively, the EFB needs to have a consistent pairing with an effective social indicator such as the Canadian Index of Wellbeing.

There was significant resistance from academic and community participants on taking stock of natural capital as it does not answer the cultural devaluation of nature and may even exacerbate it. Groups that work with Indigenous communities cite significant skepticism regarding empirical data coming out of universities using traditional sciences, given that it has historically been used to make policy that leads to systemic disadvantages. Many participants questioned the ethical standpoint of claiming that the EFB is “just data” and suggested that it is part of the larger socio-ecological problem without a normative framing for acceptable use of that data.

While the individual footprint calculation tool was a well-known and appreciated tool, there was broad recognition that it did not sufficiently help impact an individual’s actual decisions and behaviour. Indigenous actors pointed out the cultural insensitivity of the individual footprint calculator citing the example of red meat. If a person consumes a great deal of red meat, their footprint significantly increases. However, red meat consumption is integral to some traditional cultures. There were concerns and questions raised regarding how the EF incorporates Indigenous knowledge and how it accounts for Indigenous-owned land. EF research is currently missing an essential separation between settler and Indigenous-owned/occupied land. The approach demonstrates the use of hectares without considering political ownership, whose land, and if certain areas owned and operated by different groups are used more or less. This is a significant area for future research.

Many participants recognized the individual footprint tool as an effective educational method for individuals. However, municipal actors argued that education is not an effective way to make an impact and that individual action is not the right approach. Instead, that change needs

to be made through policy implementation and regulation. However, they also did not see data as a highly effective strategy for large-scale and long-term change, mainly because of anti-environmental political pressures. This suggests that the growing culture of misinformation and devaluation of empirical scientific knowledge permeates at least some levels of Canadian governments.

Key Takeaways

1. There is little documented use of the EFB in Canadian regional, provincial, or federal policy development and decision-making. There is significant interest in adopting the methodology; however there is a perceived issue regarding ease of access and ease of use. Most believe that they need to hire a statistician to meaningfully engage with the data. Development of a standardized methodology to collect and analyze disaggregated granular data is the main priority.
2. At the provincial level, there is significant demand for assessing Canada's natural capital to measure decision-making impacts over time. Provincial actors are not interested in the monetary valuation of natural capital but in the data to demonstrate measurable impacts for persuasion. Taking stock of nature will help to create better long-term policy and definite, instead of estimated, measurements of Canada's natural spaces.
3. There is a demand for the monetary valuation of nature and environmental decision-making at the municipal level. Municipal actors need to know specifics regarding the cost of action and inaction to make cases for purchasing of infrastructure, recreational activities, and development of informed bylaws.
4. In the literature review, there was some indication of issues concerning cultural inclusion and well-being, this was also expressed in the interviews. The literature critiques the tool's anthropocentric nature and that as a wholly environmental indicator, the tool has major implications. This view was shared among actors, particularly Indigenous actors, who would like to see the tool used to better understand how Indigenous cultures improve biocapacity.
5. Across all actors there is a significant interest in collaboration on future projects. This ranges from the desire to be a part of the research development process and deep integration in the research program to the openness to be one element within a larger study.

Objective 3: Data Sensitivity Analysis

We were challenged to narrow the scope of our sensitivity analysis by finding that Canadian-sourced data sets were in many cases not as complete as the international data, so it was difficult to compare the two to assess robustness. We settled on evaluating data used for two main footprint components: forest and cropland, by comparing the internationally-sourced data (from the United Nations Food and Agricultural Organization, FAO) with nationally-sourced data from Statistics Canada. We began our analysis with data about forest products and

thereafter we evaluated the areas and harvested of various crops in Canada, for the year 2015 reported in the 2021 edition of the accounts.

After an exhaustive search of Statistics Canada and Natural Resources Canada for Canadian-sourced data on forest products, we found that the most complete source of Canadian data remained the UN FAO which is currently used to produce the accounts at a national (and international) level. Canadian data was highly fragmented.

Another major EF component included as part of this analysis was cropland. We searched Canadian-based crop statistics for discrepancies between these data and the internationally-sourced data currently used to generate the national accounts. We found that there were no discrepancies between Canadian sourced data sets and currently used internationally sourced data sets. Data for crop products from Canadian national sources were accessible but was not as comprehensive as our current working data. Nonetheless, this relatively small list of products provided valuable insights. Our current working data sets have a much more comprehensive list of crop products in a unified data set than those obtained from Canadian national sources. This is important because it reflects that even though there is no significant alteration to the data itself, FAO data collection structures likely require reporting of cropland data from a series of Canadian statistical reports and brings it together in a way much more supportive of the needs of the NFA. This strengthens the argument in favour of using current internationally sourced data for the generation of the NFA.

Key Takeaways

1. Internationally-sourced data about Canadian crops and forest products from the United Nations is a more comprehensive public source of information when compared to what we could find reported by Statistics Canada and Natural Resources Canada.
2. The sensitivity analysis was limited by the lack of available data that we could use as a direct comparison to our existing data sets. We envision needing to structure a follow-on project with Statistics Canada to better access Canadian data and to understand the process and any associated controls with national submission of data to international databases such as the ones used to generate the national accounts.
3. Work is ongoing to test the sensitivity of the national accounts to random differences in the Equivalence Factor (EQF) and Ocean Uptake and Net Annual Increment (NAI). Ongoing results will help to inform the work of a Science Advisory Committee of the Footprint Data Foundation that is tasked to recommend methodological improvements.

Strengths and gaps of research

The approach taken for the literature review was highly rigorous. Each article was coded individually by two researchers who then met in a reconciliation meeting to ensure all themes and ideas were presented appropriately. The interviews and stakeholder engagement were

conducted through a large network of practitioners and scholars who are also networked widely and have a broad sense of NGOs and decision makers' opinions and positions.

The most impactful limitation in ascertaining the EFB with stakeholders was the lack of clear understanding of the methodology's technical mechanics. It may have been beneficial to provide participants with a toolkit that clearly presented the limits and opportunities of the EFB. No such toolkit exists and should be a priority for development to help establish meaningful collaborations. Due to the widespread misunderstanding of the tool, we did 18 interviews instead of the planned 25-30, we will conduct a focus group with the rest of our actors that would start with a brief overview. We did not want to continue interviews with stakeholders knowing this problem existed. Stakeholders were also willing and eager to participate in collaborations, but we were not prepared to offer timelines or direct routes to immediate collaboration. At the focus group, we will focus on a more concrete and collective research agenda.

IMPLICATIONS

Outcomes of this research project have wide-reading implications for policy and decision makers and academic research programs related to the Ecological Footprint and Biocapacity. Findings help inform the future direction of research and program planning for the Global Ecological Footprint Network, the Footprint Initiative at York University, and the Footprint Data Foundation.

Through the codified literature view of 250 English-language publications on the footprint approach over the last decade, we present a deeper understanding of the state of research regarding the footprint. This process isolated critiques of the footprint to help establish a research agenda based on the approach's perceived weaknesses. By assessing the limitations of the approach proposed by outside scholars, this synthesis helps to improve the methodology through a research agenda that responds to the critiques accordingly.

The knowledge synthesis demonstrates how the Ecological Footprint Initiative can help better measure Canada’s progress on the Sustainable Development Goals. Most directly, the Footprint can be used as an indicator within specific targets of some of the less normative biocapacity goals, such as SDG 14 and 15, Life Below Water and Life on Land, respectively. Interviews with the stakeholders suggest that the footprint should also be used to measure progress on SDG 12: Ensure sustainable consumption and production patterns. On the Sustainable Development Goals Hub a "material footprint" measure for the "sustainable management and efficient use of natural resources" is flagged to be "exploring data sources" (https://www144.statcan.gc.ca/sdg-odd/goal-objectif12-eng.htm).

Our conversations with staff at the Hub identified a strong interest in revising this metric to use Ecological Footprint and Biocapacity since this better relates the capacity of lands and waters to sustain consumption and production. The accounts demonstrate Canada's exports are significantly more footprint-intensive than imports and the Canadian consumption. About 57% of this footprint was used to produce exports, which is disproportionately large considering that Canada exports about 30% of domestic production. In 2017 more than twice as much Biocapacity was used per dollar of Canadian exports than per dollar of Canadian imports; this difference was even larger in prior years since being measured in 1961 (Figure 8).

By assessing the supply of knowledge and the demand for this knowledge, our synthesis identifies gaps that our identified research agenda will address. Our work will inform the Science Advisory Committee of the Footprint Data Foundation, with their outcome of identifying priorities for enhancements and refinements of the accounts and clarifying how the accounts relate to other measures of human use of the Earth's carrying capacity. This will inform the Foundation and the future evolution of the National Ecological Footprint and Biocapacity accounts, given an existing commitment of the Foundation to evolve the methodology and to publish yearly updates to the data series.

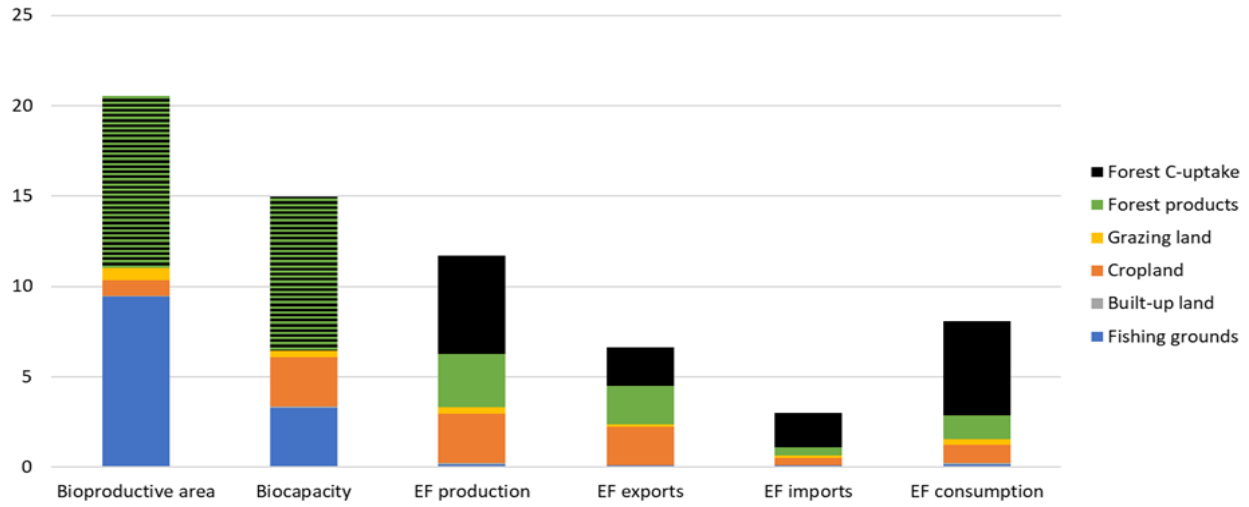

Figure 9: Measures of Canadian EF on an average per-capita basis, in global hectares, as compared to Biocapacity. Canada's EF measured on a consumption basis includes the EF of imports and subtracts the EF of exports from the EF of production. Canada's production for exports has a disproportionately high EF.

Furthermore, our knowledge synthesis demonstrates how carrying capacity is used in management, including targets and threshold for policy development, the role of natural capital in decision-making, and the most helpful aggregation level for changemakers. We uncovered the kinds of knowledge that changemakers find legitimate (academic versus governmental data) to ensure appropriate future partnerships. We now know that the development of provincial accounts with university team-leading collaborations and a toolkit for quick and informative details on the EFB for a broad array of engagements are the most immediate priorities.

We offer three key policy implications that are relevant to all levels of governments in Canada:

1. Living within the Earth's carrying capacity requires accounting systems and metrics that are jurisdictionally scalable and relatable to trade. Management of carrying capacity in Canada is mostly provincial, so provincially-scalable measures are needed. These should also map to national and international economic accounts that track trade flows. Ecological Footprint and Biocapacity accounts could fulfill this role if they were better understood and developed.

2. Pan-Canadian interest in "nature-based solutions" to reduce climate change and stop biodiversity loss requires an integrative area-based accounting of carrying capacity. The path to a carbon-neutral Canadian economy involves challenging trade-offs, such as using arable lands for afforestation to sequester carbon, versus producing ethanol, versus food, versus settlements. These demands can add pressure upon scarce biodiversity. Ecological Footprint accounting can help to measure competing demands on Biocapacity.

3. Government-financed economic stimulus should be informed by metrics beyond jobs and Gross Domestic Product (GDP). Even with abundant carrying capacity in Canada, about 78% is needed to sustain domestic production, with the remainder used for sequestration in a world that is already in overshoot of the sustainable global supply. Footprint accounting could be used to evaluate the additional direct, and indirect, pressures on Biocapacity implied by economic stimulus.

Our findings point to important opportunities to mobilize knowledge to policy communities, and to co-create addition knowledge. We envision a) collaborations between footprint-focussed research groups and provinces across Canada to develop provincial data accounting for better policy, b) co-developing research agenda between policymakers, NGOs, Indigenous communities, and academic groups and, c) helping sub-national decision-making by providing sub-national data to inform specific, detail-oriented, and environmental decision-making regarding infrastructure and recreational projects.

The production of National Ecological Footprint and Biocapacity Accounts involves over a dozen parameters that relate to dozens of input tables that together encompass over a hundred fields populated with millions of records. Considering that some input data can be sourced locally or provincially as a substitute for national or international data, our sensitivity analysis helped to understand the significance of potential substitutions in the future. This will help to address some questions we encountered in the literature, such as using ranges rather than point values, and from Canadian policy professionals about using nationally-sourced data as a substitute for internationally-sourced data (assuming they are different). This activity also aimed to inform the research priorities of the Science Advisory Committee of the Footprint Data Foundation which is tasked to recommend changes to the accounting methodology.

As a result of our multi-directional knowledge mobilization activities, we have enhanced research collaborations through engagement with others and we have added to our network of contacts related to the York University-led Ecological Footprint Initiative. Academic interest and expertise in the broad realm of environmental indicators and accounting systems is diffused across Canada; our deliberate goal of engaging and interviewing others has enhanced our profile and generated new collaborations.

Our synthesis has generated pedagogically useful outputs and enhanced the students' skills and experience of those who have helped us acquire and synthesize knowledge. The students have gained experience in applying qualitative and quantitative research methods considering the scope of our work that includes scholarly knowledge synthesis, interviews with current and potential knowledge users, and quantitative sensitivity analysis of the National Ecological Footprint's existing product Biocapacity accounts. Future cohorts of students will also benefit from the project's deliverables being used in the York University courses Ecological Footprint Accounting and Ecological Footprint Analytics.

CONCLUSION

The literature reviewed uncovered a lack of understanding and misinterpretations regarding how the accounts work. This confusion was further identified in the interviews with stakeholders, which creates a major barrier to using the EFB in policy development. Misinterpretations of the accounts lead to many questions and criticisms from academics, often due to misinformation, lack of information, or misunderstanding. This needs to be addressed through more methodological articles and responses (e.g., Borucke et al., 2013; Goldfinger et al., 2014; Rees & Wackernagel, 2013) and methodological updates and guides, some of which already exist for academics (Lin, Hanscom, Martindill, et al., 2018), but are also deeply necessary for policymakers and stakeholders.

These misunderstandings are also apparent among real-world actors. Many are unaware of what the opportunities and limitations of the tool are. This suggests the need for a public awareness toolkit that can help municipalities apply the footprint to their policy work and to NGOs to help disseminate lessons easily available through the EF tool. Non-experts need more accessible and easier to use guides that explain the accounts and describe how to use them. The latter half is more difficult, given that the specified use of the accounts may require specific expertise.

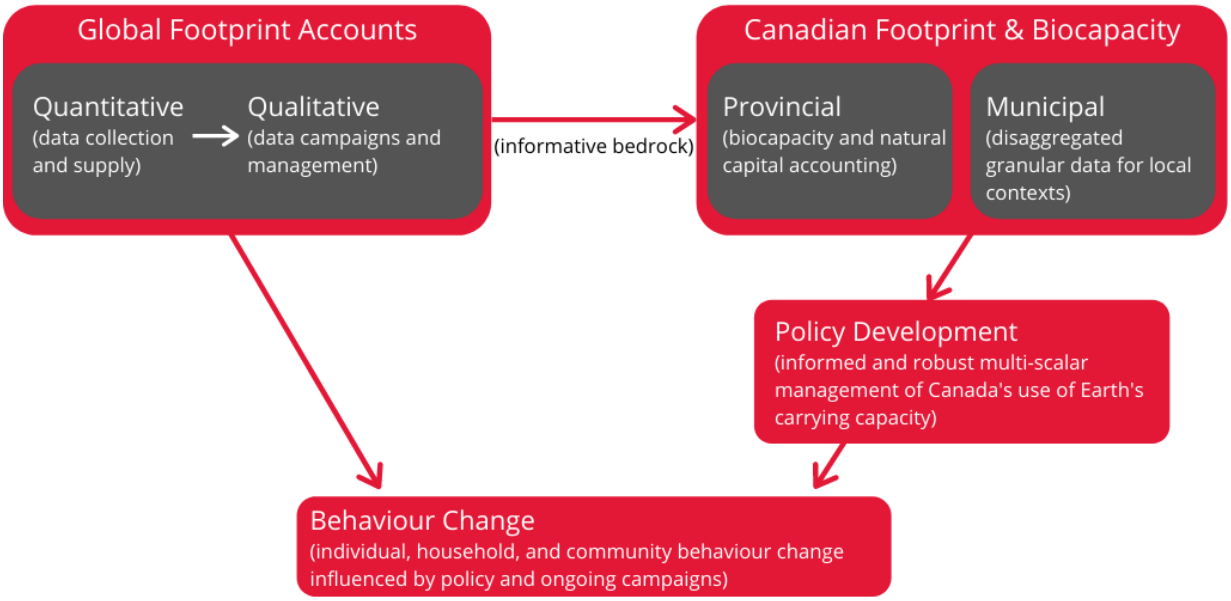

Figure 10: Key components of a research agenda for the Ecological Footprint in Canada

Future Work

This project's primary outcome is identifying critical components of an immediate and long-term research agenda for the Ecological Footprint in Canada (Figure 7).

Despite misunderstandings, the ubiquity of the footprint remains strong in academia, public settings, and among policymakers. With deeply uncertain but certainly challenging times ahead, there is a continued need for a clear methodology and accounting system that helps make the best decisions at all scales and demonstrates, very easily, how well Canada is doing in response to our environmental emergencies. Actors across Canada demonstrate significant interest in collaborations to mobilize a cross-sector and cross-spatial scale research agenda that mobilizes the EFB.

Such a research agenda in Canada should center around four specific themes, defined largely by their scale of approach:

1. Continuation of the Global Footprint Accounts including collecting, sanitizing, and uploading the data to continue to empower academic and independent work using the data. This will help continue the gradual increase of EFB research outputs and continued innovation of the tool.
2. Provincial biocapacity accounting in Canada to take stock of natural capital to be proactive rather than reactive to use of natural resources across the country. Given that the sensitivity analysis demonstrated that the GFN accounts are the most comprehensive, creating provincial accounts to compare against federal accounts would be beneficial.

3. Municipal policy development strategies including the disaggregation of data and development of easily implementable methodologies for applying EFB to municipal settings. Additional disaggregation and GSP mapping efforts need to be employed to delineate whose land (settler or Indigenous-owned and/or occupied) is used and if Indigenous governance improves biocapacity use.
4. Research regarding the effectiveness of current campaigns on individual and household behaviour change and ascertaining how the EFB could do this better. Research in this area would bring together behaviour economists and ecological economics.

KNOWLEDGE MOBILIZATION ACTIVITIES

Multi-directional knowledge mobilization is key to our objective of synthesizing knowledge that will help to enhance the understanding and use in Canada of Ecological Footprint and Biocapacity.

Knowledge obtained and synthesized through this project was disseminated through various platforms. While we intended to travel to Ottawa to present the grant's outcomes at a Knowledge Briefing, this was changed to an online webinar due to travel restrictions and advisories from Health Canada regarding the COVID-19 pandemic. The research outcomes were also presented on three live webcasts through the Leadership for the Ecozoic Webinar Series at the University of Vermont, the Sustainability Network, and Sustain What? at Columbia University, and one hosted by the Global Footprint Network. Researchers presented outcomes at the Canadian Society for Ecological Economics Biennial conference through participation is a Well-being Alliance Problem Lab, two spotlight presentations by members from the research groups, and with a “table” on the conference floor with short demonstrates of research outcomes and daily discussion questions for delegates to engage with.

To synthesize and transmit knowledge, we also delivered this Synthesis Report and an accompanying Evidence Brief on the state of the knowledge and its demand by actual and potential end-users, with identification of gaps and opportunities, including data-related ones derived from our sensitivity analysis. We produced a Video Brief as a 5-minute web-hosted (HTML5-compatible) overview of our knowledge synthesis to attract visibility and interest in our other deliverables and our team’s research.

Presentations

January 22nd, 2021. 2021 Edition of the Ecological Footprint and Biocapacity Accounts. Ecological Footprint Initiative. York University.

Speakers: Eric Miller, David Lin, Peter Victor, Chaya Kapoor, Mark Milnes, Sophie Angoh

February 24th, 2021. The Ecological Footprint in Action. Anthropocene to the Ecozoic Webinar Series. McGill University and the University of Vermont.

Speakers and links to presentations:
Katie Kish: https://www.youtube.com/watch?v=W301gP-efMg&t
Mark Milnes: https://www.youtube.com/watch?v=UMOPK7_K0ts
David Lin: https://www.youtube.com/watch?v=B9weINHyzpk

Date TBD, 2021. The Ecological Footprint Accounts. Sustainability Network Webcast. Sustainability Network, Online.

Speakers: Katie Kish, Eric Miller, David Lin, Peter Victor

Date TBD, 2021. The Ecological Footprint and Behaviour Change or Pandemic or Wellbeing. Sustain What? videocast. Columbia University's Earth Institute, Online.

Speakers: Eric Miller, Katie Kish, Mark Milnes, David Lin

March 25th, 2021. Canadian Demand for the Ecological Footprint: Natural Capital & cultural inclusion. Ecological Footprint Initiative. SSHRC, Online.

Speakers: Katie Kish, Eric Miller

April 21st, 2021. The Ecological Footprint. Scholars Hub Earth Day Presentation. York University, Online. Speakers: Eric Miller, Katie Kish

May 2021. Global Biocapacity Accounting. State of Ontario Biodiversity, Online.

Speakers: Eric Miller

May 27-29, 2021. Using the Ecological Footprint Data for Policy Development. Problem Lab at Canadian Society for Ecological Economics Biennial Conference. Canadian Society for Ecological Economics, Online

Speakers: Eric Miller, Chaya Kapoor, Mark Milnes

May 27-29, 2021. The Ecological Footprint. Spotlight Presentation at Canadian Society for Ecological Economics Biennial Conference. Canadian Society for Ecological Economics, Online.

Speakers: Chaya Kapoor

May 27-29, 2021. The Ecological Footprint. Daily Table Talks. Canadian Society for Ecological Economics, Online.

Speakers: Katie Kish, Eric Miller, Peter Victor, Mark Milnes, David Lin, David Mallery

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Del Bianco A., D. Mallery, K. Paudel, M.J. Bunch. 2020. **The Exploration of Socio-Ecological Approaches and Indicators in the Anthropocene.** In Katharine Zywert and Stephen Quilley (eds.) Health in the Anthropocene: Living Well on a Finite Planet (pp 357-382). Toronto: University of Toronto Press.

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