Ontario's Ecological Footprint and Biocapacity: Measures and trends from 2005 to 2015

By Eric Miller, Jason Robinson, Maria-Louise McMaster, Elizabeth Holloway, Anuja Kapoor.
For the Ontario Ministry of Natural Resources and Forestry. Updated August 2021.

Recommended citation:

Miller, E., Robinson, R., McMaster, M.-L., Holloway, E., and Kapoor, A. (2021). Ontario's Ecological Footprint and Biocapacity: Measures and trends from 2005 to 2015. Report submitted to the Ontario Ministry of Natural Resources and Forestry.

Authors are affiliated with the York University Ecological Footprint Initiative. The York University Ecological Footprint Initiative can be reached at footprint@yorku.ca

The authors thank Dr Connie Ko at York University for geomatics assistance.

Cover photographs from Eric Miller, used with permission.

Contents

Introduction

Ontario's lands and waters sustain a great diversity of ecosystems and species. Through a complex web of inter-relationships, these ecosystems and species transform materials from the landscape, and energy from the sun, into products and processes that sustain life. Humans depend upon ecosystems, and the life that they sustain, as sources of food and materials and energy, and as a means of metabolizing wastes, and as places for settlements and infrastructure. This dependence has a greater chance of being sustained if humans use renewable natural resources at rates that can be regenerated, and if humans emit pollution at rates that can be metabolized. These conditions necessitate the measurement of humanity's use of the regenerative capacity of ecosystems around the world. This can be accomplished by accounting for Ecological Footprint and biocapacity.

An Ecological Footprint measures the area needed to supply humans with food and fibres, forest products, lands for settlements and infrastructure, and the sequestration of anthropogenic carbon emissions. This can be compared to biocapacity, which is measured as the potential for lands and waters to sustain an Ecological Footprint. Ecological Footprint and biocapacity can be compared to each other because they are expressed in the same units of global hectares. Measures and comparisons are regularly published as the National Ecological Footprint and Biocapacity Accounts with the most recent 2021 edition published in 2020 (York University and Global Footprint Network, 2020). These national accounts were downscaled to generate results for the province of Ontario.

Over time, Ontario's ecosystems have become increasingly affected by humans, from population growth and from growth in the consumption of materials, energy, and space. This growth is a threat to biodiversity in Ontario (Ontario Biodiversity Council, 2015) in a global context of declining biodiversity (IPBES, 2018). An Ontario Biodiversity Strategy was established in 2005 and renewed in 2011 to guide conservation in Ontario with a focus on goals and targets (Ontario Biodiversity Council, 2011). This strategy has an objective of reducing Ontario's Ecological Footprint, with a requisite action of reviewing and refining a suite of indicators that includes Ecological Footprint, and its relation to biocapacity. To that end, this report provides measures and trends from 2005 to 2015 that can inform the Ontario Biodiversity Strategy through the leadership of the Ontario Biodiversity Council. This report also aims to broadly inform Ontarians about how their consumption relates to the use of lands and waters at home and abroad, which puts pressure upon biodiversity.

Ecological Footprint of consumption in Ontario

Ontario's Ecological Footprint of consumption is the area of the planet that is needed to supply Ontario's consumption of food and fibres and forest products, Ontario's use of lands for settlements and infrastructure, and the sequestration of anthropogenic carbon emissions that result from consumption in Ontario. This follows the convention of the National Ecological Footprint Accounts (York University and Global Footprint Network, 2020). An Ecological Footprint can be detailed as the sum of six components, which are defined in Table 1: fishing grounds, cropland, grazing land, forest products, built-up land, and forest carbon uptake. The term "forest carbon uptake" is used in this report rather than the simpler term "carbon" (used in the national accounts) to clarify that it measures the lands of forests that are required to sequester carbon emissions, which are beyond the amount sequestered by the world's oceans (which were 29% of global emissions in 2005, 28% in 2010, and 30% in 2015). Ocean sequestration is applied in the national accounts to all anthropogenic emissions without any distinction of whether the emissions came a coastal jurisdiction. Therefore, the same approach was applied to Ontario.

Table 1: Components of Ecological Footprint, which are all measured annually in global hectares (gha).

Fishing grounds	Area of marine and inland waters needed for human consumption of fish, invertebrates, aquatic mammals, and aquatic plants
Built-up land	Area of land occupied by human-built infrastructure, including housing and other buildings, roads and paved areas, and urban greenspace
Cropland	Area of land needed to grow crops consumed by humans as food or fibres, and for crops fed to animals and fish that are consumed by humans
Grazing land	Area of land needed to feed livestock consumed by humans, beyond the feed supplied by the cropland component
Forest products	Area of land needed for forest harvests to derive pulp and timber products
Forest carbon uptake (Forest c-uptake)	Area of forests needed to sequester anthropogenic carbon emissions (beyond emissions sequestered by the oceans) from combustion of fuels and electricity generation, plus carbon emissions embodied in traded electricity and globally traded goods inclusive of their global transport emissions

Components are each measured in a standardized unit of a global hectare (gha) to allow them to be summed and compared to an Ecological Footprint calculated at any level of aggregation anywhere on the planet, in any year. A global hectare is a hectare of the planet that provides a global-average amount of annual biological production. Global hectares can be converted to, or from, a hectare in Ontario by applying several conversion factors that are related to the specific footprint component being converted. For example, the

conversion of a hectare of Ontario cropland growing carrots to a global hectare involves a different conversion than a hectare of forest. Detailed factors are found in the appendix. This report's measures of Ecological Footprint are often provided on a "per capita" basis, by dividing the Ecological Footprint, or any of its components, by the population in Ontario in that year. This results in a statistically average Ecological Footprint, which allows it to be compared to statistically average measures for Canada or any other country in the world. Readers should keep in mind that statistical averages do not communicate any information about the distribution of values that are averaged. The Ecological Footprint of an individual living in Ontario varies widely depending upon their level of consumption and lifestyle, which can reflect choices and constraints that relate to various factors including age, socio-economic status, geography, and living arrangements. Variabilities in per-person footprints could not be estimated because the requisite statistics were unavailable.

Readers should keep in mind that biodiversity is affected by the total Ecological Footprint rather than its per-capita measure. Changes in an average per capita footprint must also be considered together with any changes in the corresponding number of humans. Several frameworks beyond this report have been developed to communicate and account for the full impact of human pressures upon biodiversity. One common framework is referred to as I=PAT to approximate that human impact is a function of the size of the Population (P) and the average Affluence of the population (A) and the nature of Technology (T) that can amplify or diminish impacts. Ontario's population has grown and is forecast to grow (Statistics Canada, Table 17-10-0005-01, 2020) alongside policies that are meant to accommodate and encourage growth in human populations (e.g. Places to Grow Act, 2005, Growth Plan for Northern Ontario, 2011) and economic activities. Ontario is assuming a growth of 5.2 million people in Ontario from 2019 to 2046 (Ontario Ministry of Finance, 2020). The resulting pressures upon biodiversity will also depend upon any future changes in per-person affluence and technologies used in Ontario and around the world.

Since 2005, about one third of all goods and services produced in Ontario are exported to the rest of the world, and about one third of all consumption in Ontario is from imported goods and services (Statistics Canada Table 36-10-0222-01, 2020). This is about the same proportion as for Canada, calculated in the same way using Gross Domestic Product (GDP) data from the Economic Accounts of Canada compiled by Statistics Canada. On a net basis, about two thirds of all economic production in Ontario is consumed in Ontario. The Ecological Footprint *of consumption in Ontario* is intended to reflect Ontario's share of the Ecological Footprint of components that are produced domestically, minus the portion of the components that are exported, plus the footprint of components that are imported. The result is an Ecological Footprint that measures Ontario's share of the consumption in

Canada of Canadian-produced goods, plus the footprint of imported food (crops, livestock, and fish products), fibres, forest products, and carbon emissions attributable to imports, while excluding the Ecological Footprint corresponding to exports to the rest of the world.

Results by footprint component

The Ecological Footprint of consumption in Ontario was 132.8 million gha in 2005. In 2010 it was 106.4 million gha and in 2015 it was 96 million global hectares. This amounts to a 28% decline from 2005 to 2015. Figure 1 illustrates this decline while also detailing the footprint components that sum to the total. To better understand the relative size of each footprint component, Figure 2 presents the same data as a proportion of the total.

Figure 1: Ontario Ecological Footprint in millions of global hectares (gha).

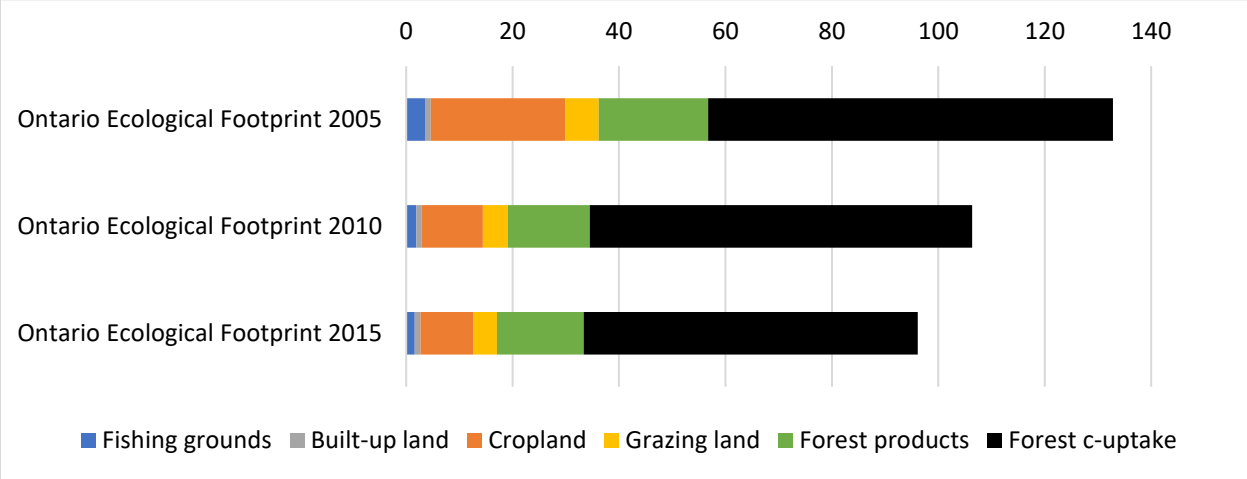
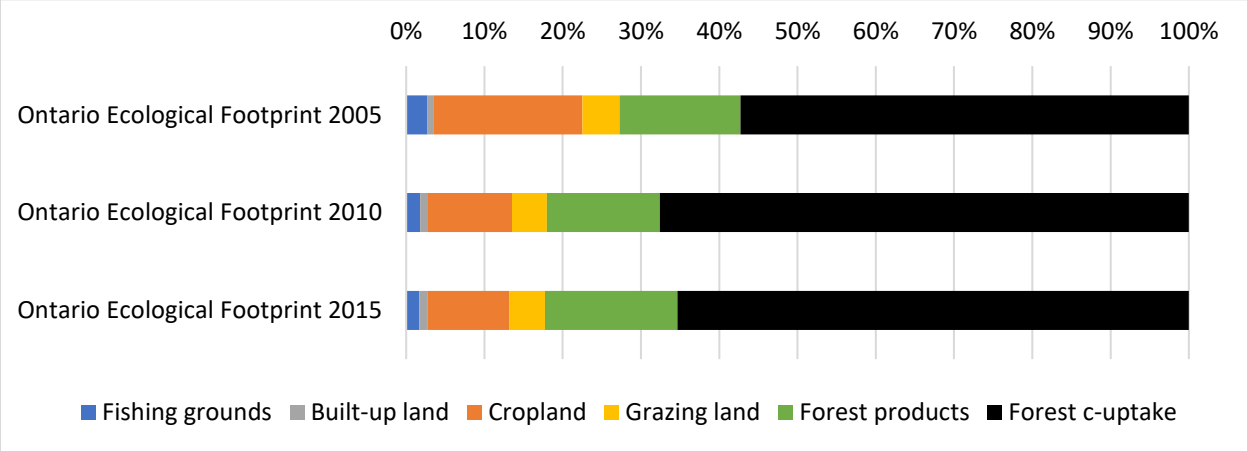


Figure 2: Component share of Ontario's Ecological Footprint in each year.

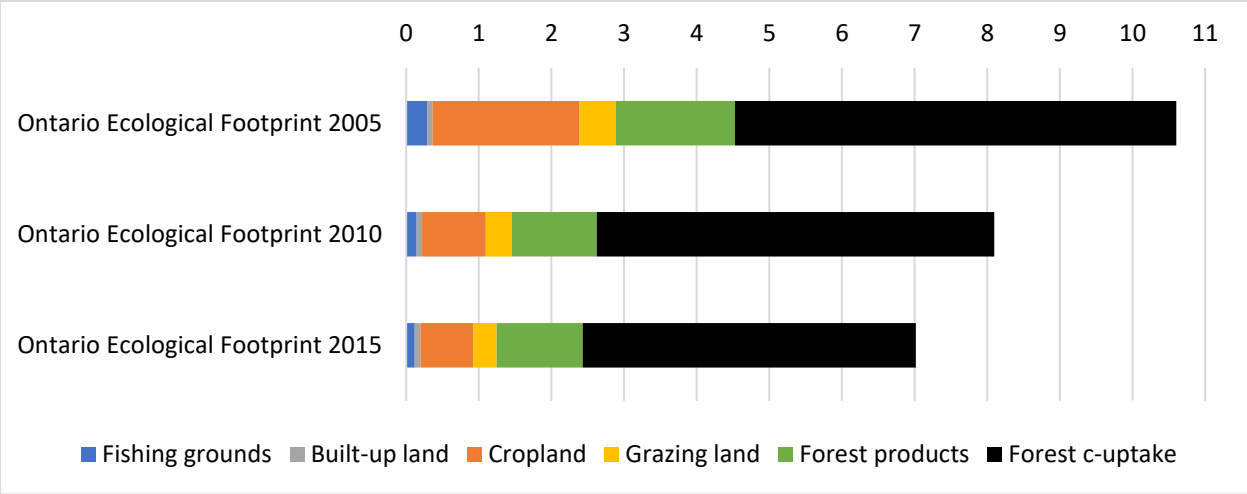


Carbon emissions attributed to consumption in Ontario was the largest component of the Ecological Footprint in all years. This is represented by the forest carbon uptake component, written as "forest c-uptake". The second-largest footprint component in all years was forest products, followed by cropland, grazing land, fishing grounds, and built-up land. Built-up land was the smallest component in all years and the only one that grew.

From 2005 to 2015, the cropland component of Ontario's Ecological Footprint declined the most of any component, on an absolute and relative basis. Its 2015 value of 10 million gha was 60% smaller than its value of 25.3 million gha in 2005. The built-up land component remained the smallest component over all the years and is also the only component that grew. In 2015 the built-up land component of 1 million gha was 10% greater than its level in 2005. The forest products component fell by 25% from 2005 to 2010 and then grew by 6% to 2015, with a value in that year of 16 million gha.

Figure 3 presents Ontario's Ecological Footprint on a per capita basis by dividing global hectares by the Ontario population in each year. Even though Ontario's population increased by 9.4% from 2005 to 2015, Ontario's Ecological Footprint decreased enough over this period so that the net effect was a decrease in Ontario's per capita Ecological Footprint. Ontario's per capita Ecological Footprint decreased from 10.6 gha in 2005 to 8.1 gha in 2010, and to 7 gha in 2015. This is a 34% decrease from 2005 to 2015. From 2005 to 2015, the cropland component decreased on a per capita basis by 64% which is the largest reduction of any footprint component. The components of fishing grounds, grazing land, forest products, and forest carbon uptake also decreased, by 59%, 36%, 28%, and 25%, respectively. The built-up land footprint grew by 1% on a per-capita basis.

Figure 3: Ontario Ecological Footprint in global hectares (gha) per capita.



Results by good or service consumed

Ontario's Ecological Footprint is the sum of six footprint components, which were each derived by summing the footprints of specific types of consumption. As detailed in Appendix A5-A7, a Consumption Land Use Matrix (CLUM) was generated for Ontario to relate consumption spending to global hectares of land and water that were needed to sustain consumption. Ontario CLUMs were derived for 2005, 2010, and 2015, from Canada CLUMs generated for 2004, 2011, and 2014. Each CLUM identifies the footprint, by component, of almost 200 categories of consumption grouped by type and purpose.

Table 2 provides an overview of Ontario's Ecological Footprint of consumption in 2015 by footprint component and by purpose of consumption. Results are in global hectares per capita. This data is an aggregation of results from the 2015 Ontario CLUM which is detailed in Appendix A5 together with the CLUM for 2010 and 2005. Each CLUM differentiates consumption by households, consumption by government, and consumption used for the purpose of "gross fixed capital formation". Gross fixed capital formation is the creation of durable infrastructure such as residential and commercial and industrial buildings, infrastructure for transportation and communications, and military equipment. All production by companies is deemed to be either consumed by households, or consumed by government, or consumed in the process of forming gross fixed capital. Housing as a consumption category incorporates repairs and maintenance and the energy used by housing, such as electricity and water and any fuels such as gas for heating and cooking.

Table 2: Ontario Ecological Footprint in 2015, in global hectares per capita by consumption category.

Consumption Category	Cropland	Grazing land	Forest products	Fishing grounds	Built-up land	Forest c-uptake	Total
Food	0.44	0.17	0.04	0.08	0.00	0.26	0.99
Housing	0.01	0.00	0.16	0.00	0.01	0.47	0.65
Personal transportation	0.02	0.01	0.05	0.00	0.01	1.26	1.34
Goods	0.07	0.03	0.09	0.00	0.01	0.36	0.57
Services	0.12	0.08	0.15	0.02	0.01	0.63	1.02
Household subtotal	0.65	0.29	0.50	0.11	0.04	2.98	4.57
Government consumption	0.03	0.01	0.18	0.01	0.01	0.50	0.74
Gross fixed capital formation	0.05	0.01	0.51	0.00	0.02	1.10	1.71
Total	0.73	0.32	1.19	0.12	0.08	4.58	7.02

Figure 4 presents the proportion of the footprint related to household consumption, government consumption, and gross fixed capital formation, with household consumption provided in greater detail. About 65% of Ontario's Ecological Footprint was for household consumption; gross fixed capital formation accounted for 24% and personal transportation accounted for 19% of the total. Each of these consumption categories aggregate greater details, such as specific types of foods which sum up to the food portion at 14% of Ontario's Ecological Footprint. Full details are provided in the Ontario 2015 CLUM in Appendix A5.

Figure 4: Ontario Ecological Footprint in 2015, by proportion of the purpose of consumption.

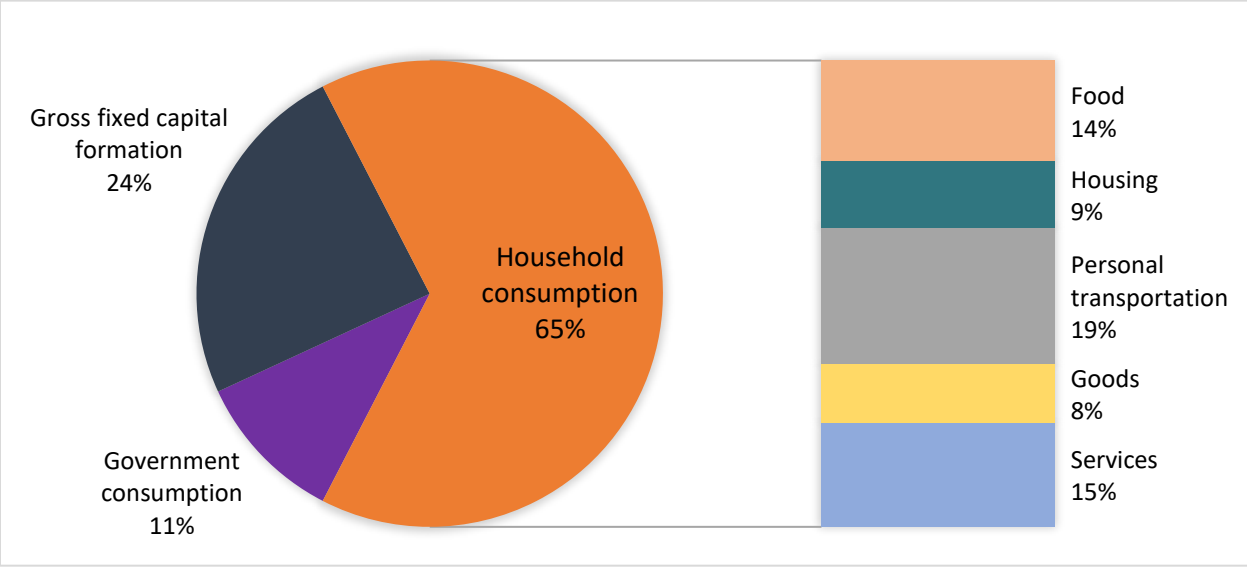


Figure 5: Ontario Ecological Footprint in 2015, in gha per capita by category of consumption.

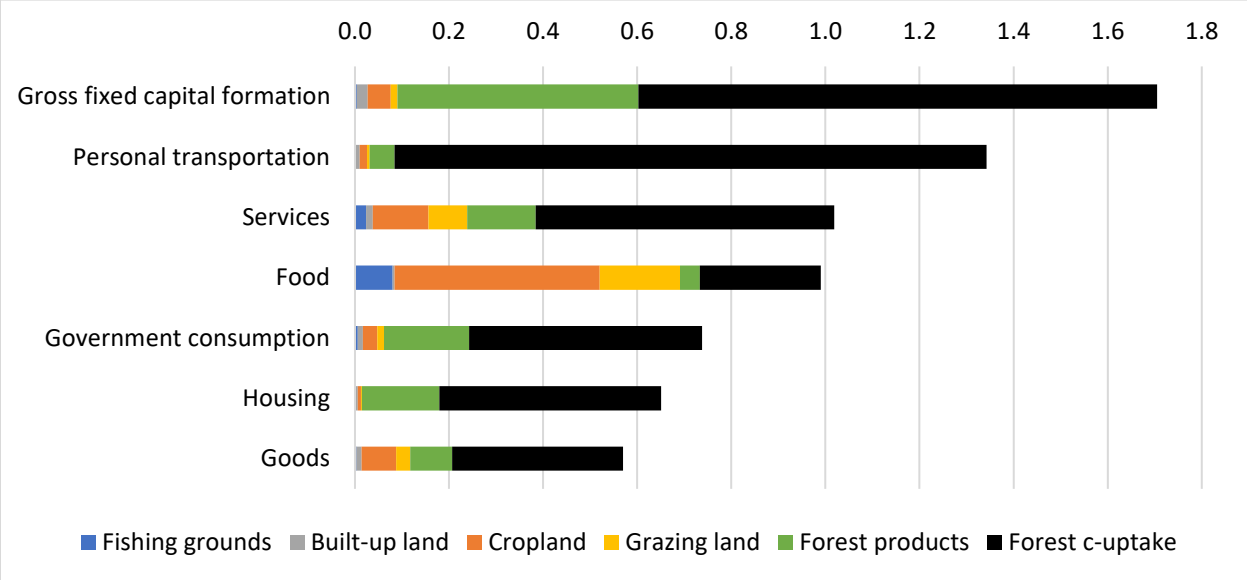
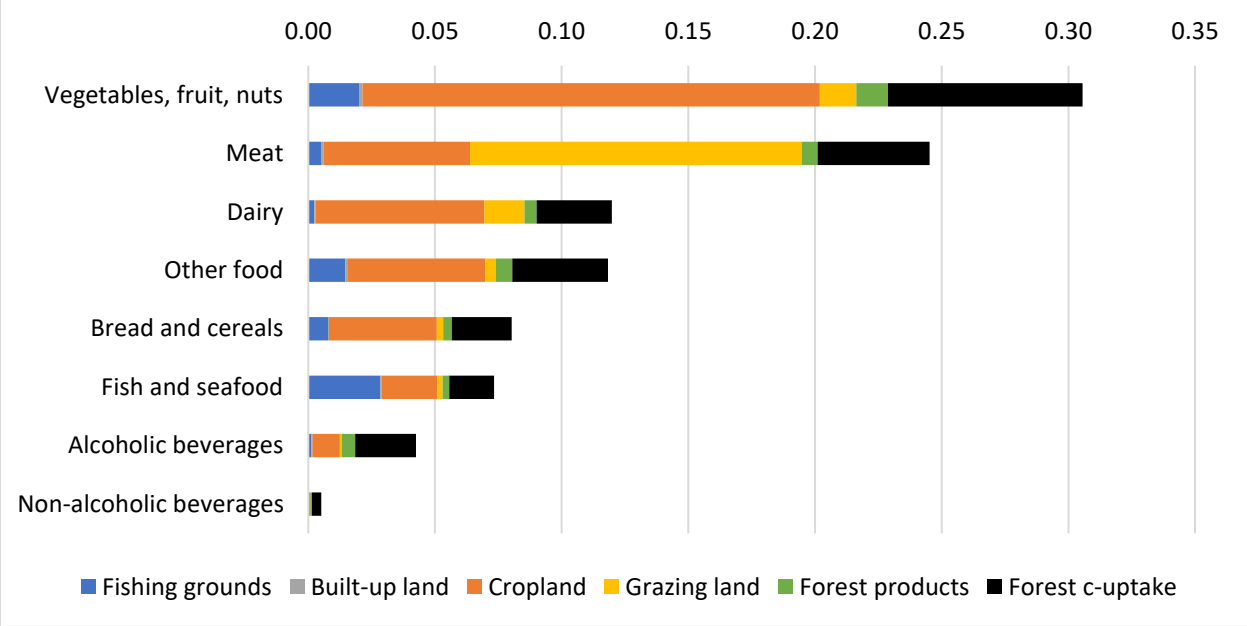


Figure 5 details how Ontario's consumption varied by the size and relative importance of different footprint components. The forest carbon-uptake component for personal transportation is greater on a relative and absolute basis than for any other category of consumption. Forest carbon-uptake was the lowest relative and absolute share of the footprint of food consumed in Ontario.

Figure 6 provides a detailed breakout of food. The footprint attributed to each category of food reflects not only the efficiency by which land is used to produce the food but also the amount of that food consumed in Ontario in 2015. Therefore, for example, results of that chart should not be used to infer that vegetables and fruits and nuts consumed in Ontario is more carbon intensive than meat or dairy, since different amounts of all were consumed. Ontario's consumption of food changed from 2005 to 2015, and was reflected in statistics about household spending (from Statistics Canada) which were combined with statistics about consumer prices to calibrate the Ontario CLUM. The CLUM also reflects how food consumed in Ontario relates to other sectors through national and global supply chains which also evolved during these years. Some types of food have footprint components that might seem counterintuitive; for example, a fishing grounds component appearing within vegetables and fruits and nuts. Fishing grounds are used by various activities along the global supply chain that is involved in supplying goods and services to the companies and workers who produce vegetables, fruits, and nuts.

Figure 6: Ontario Ecological Footprint in 2015, in gha per capita of food consumed in Ontario.



Biocapacity of lands and waters within Ontario

Biocapacity is a measure of the potential for lands and waters to sustain components of an Ecological Footprint. Like the Ecological Footprint, biocapacity is measured in global hectares so that both may be consistently compared across jurisdictions, and over time. Global hectares can be converted from, and to, hectares in Ontario using several factors that account for biological yield and equivalence, as reported later in this section and detailed in the technical appendix. Biocapacity in Ontario was calculated by classifying the entire Ontario landscape into mutually exclusive categories of land or water, then matching these to components of biocapacity with known global productivities, and then specifying how the productivity of lands and waters in Ontario compare to Canada and the world.

Table 3: Components of biocapacity described in relation to the footprint they can support.

Biocapacity Class	Includes	Footprint supported
Forest: Dense	Coniferous, deciduous, and mixed forests	Forest products or forest carbon uptake
Forest: Disturbed	Forests recently harvested or burned	
Forest: Sparse	Less dense forests amongst other landscapes	
Cropland	Orchards and areas tilled for crops	Cropland
Grazing land	Lands used to graze animals or produce fodder	Grazing land
Grassland	Grasslands not actively being tilled	
Built-up land	Buildings, pavement, manicured landscapes	Built-up land
Freshwater	All of Ontario's lakes and rivers	Fishing grounds
Wetlands: Peat Fens	Less acidic peatlands connected to groundwater flows	Forest carbon uptake
Wetlands: Peat Bogs	Strongly acidic peatlands that are less water-saturated	
Wetlands: Other	Land saturated with water	
Low Biocapacity	Natural areas with minimal vegetation	(none)
Extraction	Open pits and quarries	(none)
Unable to determine	Not specified in provincial inventories	(none)

All lands and waters in Ontario were allocated to one of 14 mutually exclusive biocapacity Classes. Table 3 describes these classes and the footprint components that they support. Areas classified as “extraction” and “low biocapacity” and “unable to determine” collectively correspond to 0.6% of Ontario; these were deemed to not support any component of footprint. All other classes support a footprint component, with forests supporting forest products or forest carbon uptake. Each class of Ontario biocapacity was derived from an aggregation of detailed provincial land-cover inventories that were used to generate an Amalgamated Land Cover (ALC). This land cover is the most recent available

data that reflects a 2015 estimate of the more heavily impacted southern portion of landscape, together with a 2014 update of an original assessment of the rest of Ontario between 2004 and 2011. Details about this methodology are provided in the appendix, which also identifies the area of each component.

The National Ecological Footprint and Biocapacity Accounts define biocapacity as the sum of five components: cropland, grazing land, fishing grounds, forest land, and built-up land. On an annual basis, forest land provides forest products when harvested, otherwise it provides the service of sequestering anthropogenic carbon emissions (after deducting the annual sequestration of carbon by the world's oceans). This dual function of forest land allows it to provide forest products or forest carbon uptake. The other four biocapacity components (cropland, grazing land, fishing grounds, and built-up land) each support one corresponding component of footprint.

About 30% of Ontario's surface area is characterized as wetlands, with three quarters of this area corresponding to fens and bogs that predominantly characterize the northern-most Hudson Bay Lowlands Ecozone. The National Footprint Accounts do not account for any biocapacity of wetlands, yet the Footprint Standards (Global Footprint Network, 2009) do permit innovations to account for locally important biocapacity. Considering the spatial and ecological significance of Ontario's wetlands, a method was innovated to account for their capacity to sequester carbon. Data about the annual carbon sequestration of fens and bogs and other wetlands in Ontario were proportioned relative to the annual carbon sequestration rate of forests in Ontario, to quantify the capacity of wetlands to annually sequester carbon. This is detailed in the technical appendix.

Built-up biocapacity in Ontario is the terrestrial area occupied by human-produced infrastructure that tends to be mostly impervious to water, although it also includes some urban recreational areas that are pervious. The same parameters are used to convert to, and from, hectares and global hectares of built-up biocapacity and the built-up component. As detailed in the appendix, the National Ecological Footprint and Biocapacity Accounts equate the yield of built-up biocapacity to the yield of cropland. Although built-up areas may incorporate urban green infrastructure that provide ecosystem services, and potentially some ecological goods such as fruit from urban fruit trees, these ecological goods and services are assumed to provide globally insignificant amounts of biocapacity. Therefore, built-up biocapacity is assumed to be only capable of supporting the built-up footprint and not, for example, offering any additional capacity for crop production or carbon sequestration.

Results by class of biocapacity

Ontario's 107 million hectares of lands and waters provided 96.8 million global hectares of biocapacity in 2015. Figure 7 illustrates this comparison with details about the individual components of biocapacity to show how their area (in hectares) compares to their productivity (in global hectares). Croplands in Ontario provide capacity that is significantly greater, per hectare, than the global average of all productive areas. For that reason, the size of cropland in the "gha" bar in the figure is much greater than "ha". In comparison, the biocapacity of grazing lands in Ontario were about the world average level, while others were below the world average. Wetlands in Ontario provided a significant amount of sequestration of anthropogenic carbon emissions, although their yield on an area-specific basis was below the global average sequestration rate of forests. For this reason, the size of wetlands in the "gha" bar on the right of the figure is less than the "ha" bar on the left. On average, lands and waters in Ontario tended to be less productive than the world average.

Figure 7: Ontario biocapacity in 2015, measured in millions of hectares (ha) and global hectares (gha).

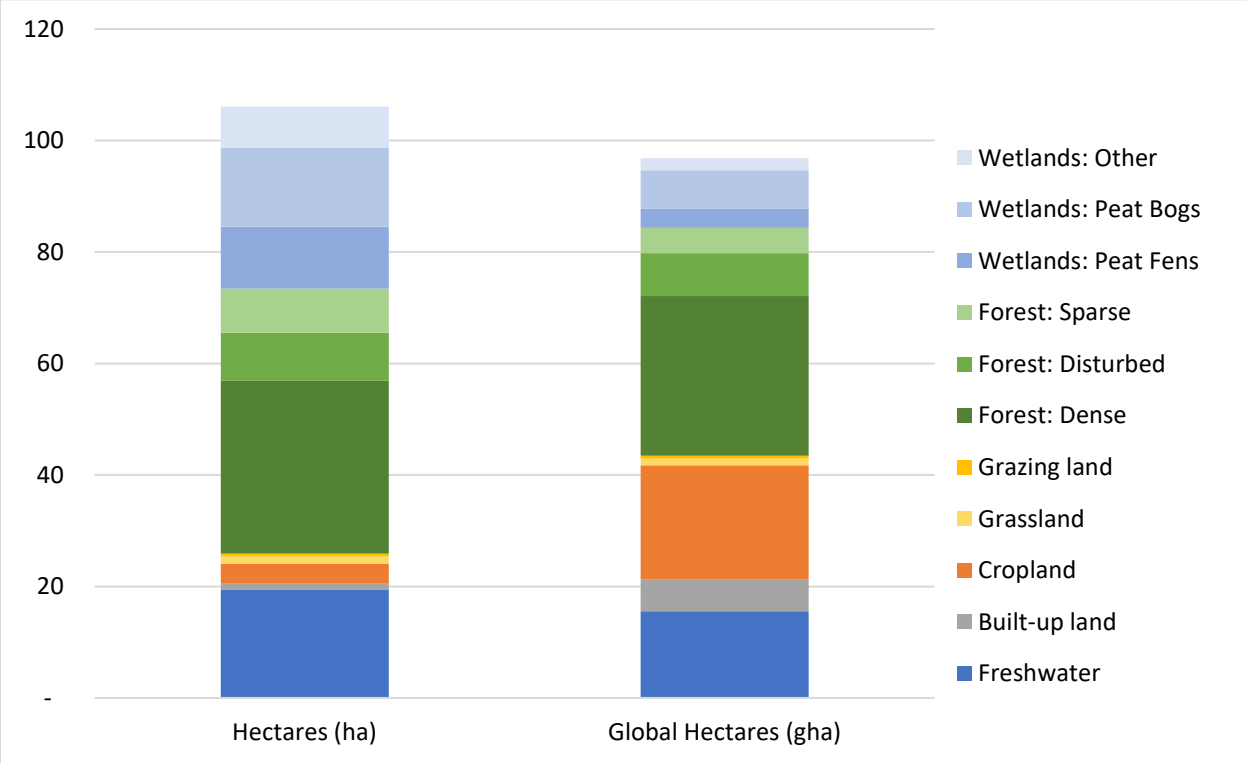


Table 4 details biocapacity in hectares by Ontario Ecozone, while Table 5 details the same in global hectares. Each table reveals differences in the distribution of biocapacity across Ontario, while both tables can be compared to understand differences in productivity.

Table 4: Ontario biocapacity in 2015, in hectares by Ontario Ecozone.

Biocapacity Class	Area (ha) in Ontario Ecozone			Total	
	Hudson Bay Lowlands	Mixedwood Plains	Ontario Shield	ha	%
Forest: Dense	1,208,376	1,435,229	28,382,013	31,025,618	29%
Forest: Disturbed	727,219	-	7,866,870	8,594,089	8%
Forest: Sparse	967,124	399,303	6,550,600	7,917,026	7%
Cropland	-	3,510,244	137,195	3,647,439	3%
Grazing land	-	425,146	99,753	524,899	0%
Grassland	-	1,017,613	215,536	1,233,149	1%
Built-up land	2,776	720,363	312,967	1,036,106	1%
Freshwater	2,090,946	5,268,646	12,077,268	19,436,860	18%
Wetlands: Peat Fens	8,307,854	6,364	2,810,406	11,124,624	10%
Wetlands: Peat Bogs	9,484,508	14,062	4,668,704	14,167,273	13%
Wetlands: Other	1,912,911	693,091	4,752,096	7,358,099	7%
Low Biocapacity	72,251	25,872	328,509	426,631	0%
Extraction	19,368	24,937	27,835	72,139	0%
Unable to determine	11,882	2,172	152,538	166,592	0%
Sum of all classes	24,805,215	13,543,041	68,382,289	106,730,545	100%
Proportion of total	23%	13%	64%	100%	

Table 5: Ontario biocapacity in 2015, in global hectares by Ontario Ecozone.

Biocapacity Class	Global Hectares (gha) from Ontario Ecozone			Total	
	Hudson Bay Lowlands	Mixedwood Plains	Ontario Shield	gha	%
Forest: Dense	951,074	1,475,930	26,251,895	28,678,899	30%
Forest: Disturbed	558,151	-	7,095,666	7,653,817	8%
Forest: Sparse	477,518	257,598	3,800,966	4,536,082	5%
Cropland	-	19,627,409	767,122	20,394,531	21%
Grazing land	-	418,825	98,271	517,096	1%
Grassland	-	1,002,485	212,331	1,214,817	1%
Built-up	15,524	4,027,885	1,749,942	5,793,351	6%
Freshwater	1,670,082	4,208,177	9,646,365	15,524,624	16%
Wetlands: Peat Fens	2,481,897	2,484	986,664	3,471,045	4%
Wetlands: Peat Bogs	4,359,095	8,444	2,521,641	6,889,180	7%
Wetlands: Other	494,537	234,114	1,443,759	2,172,410	2%
Sum of all classes	11,007,878	31,263,351	54,574,622	96,845,851	100%
Proportion	11%	32%	56%	100%	

Ontario's landscape is classified into three ecozones. The Hudson Bay Lowlands account for 23% of the hectares in the most northern portion of the province. This area is predominantly wetlands, with a cold and semi-arid climate and relatively few settlements. South of this area is the largest ecozone, the Ontario Shield, accounting for 64% of the province with an area that is predominantly boreal forest. Forest fires are a natural disturbance throughout this Ecozone, and forestry clear-cuts are common, which all result in a large portion of this forest classified as "disturbed" within the last twenty years. The Mixedwood Plains accounts for 13% of the southern-most portion of the province that is the most urbanized and intensively managed. Comparing the areas in hectares relative to their globally adjusted productivity in global hectares, the area of the Mixedwood Plains had the highest productivity, while the Hudson Bay Lowlands had the lowest. The Mixedwood Plains accounted for 26.5 million global hectares from 13.5 million hectares.

Trends in the yield of biocapacity in Ontario from 2005 to 2015

Biocapacity in global hectares was derived from data about the quantity of hectares attributed to specific land types and uses, and the yield of products from these hectares. The prior section only identifies a provincial total in 2015 because there was no province-wide land-cover and land-use inventory that differentiated all of Ontario in 2005 versus 2010 versus 2015. Land-cover and land-use changes during this ten-year period have only been (officially) estimated (by Ontario) for the southern portion of Ontario, which approximates the Mixedwood Plains. An analysis of these changes is presented later. Nevertheless, we were able to derive trends in the *yield* of biocapacity from 2005 to 2015 for inland water, cropland, grazing land, and forests.

Yield was derived from official statistics about the mass of harvests per unit of area harvested; methodological details are provided in the technical appendix. Trends in the yield of biocapacity were derived by comparing yields in Ontario to yields from the same type of land (or water) averaged across all of Canada, in the same year. Trends in yield could not be derived for wetlands because there was insufficient data about how carbon uptake may have varied from 2005 to 2015.

Figure 8 illustrates trends in yield from lands and waters in Ontario. Yields in each year were divided by the yield in Ontario in 2005, so the ratio is unit-less. All values for 2005 are therefore 1, and any value for 2010 or 2015 that is above is 1 reflects a proportional growth in yield. This normalization makes it easy to compare values over time and among all land classes. For example, the value of 0.94 for inland water in 2015 signifies that inland water in that year yielded 94% of the tonnage of fish what was yielded in 2005. Yields

from grazing land, cropland, and forest land were all greater in 2015 relative to 2005. Grazing land had the biggest relative increase, a 20% gain in 2010 over 2005, and a 30% gain in 2015 over its 2005 value. Yields from forest land in 2015 were lower than yields in 2010, but still higher than yield in 2005.

Figure 8: Trends in Ontario yields in 2015 and 2010 relative to Ontario yield in 2005.

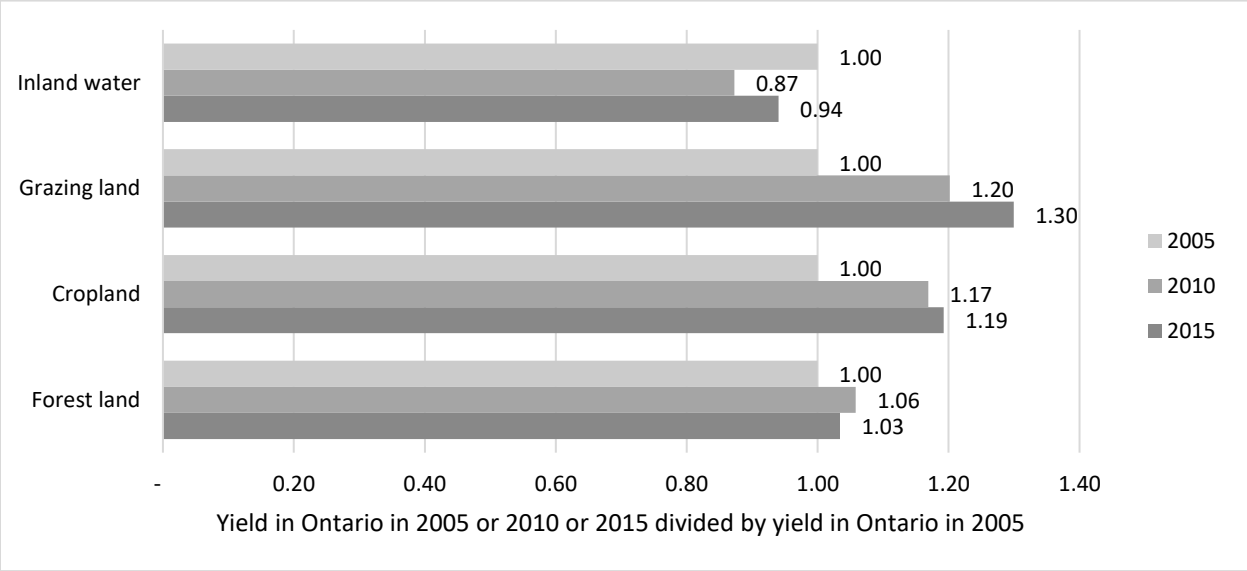


Figure 9: Trends in Ontario yields relative to Canadian yields in same year.

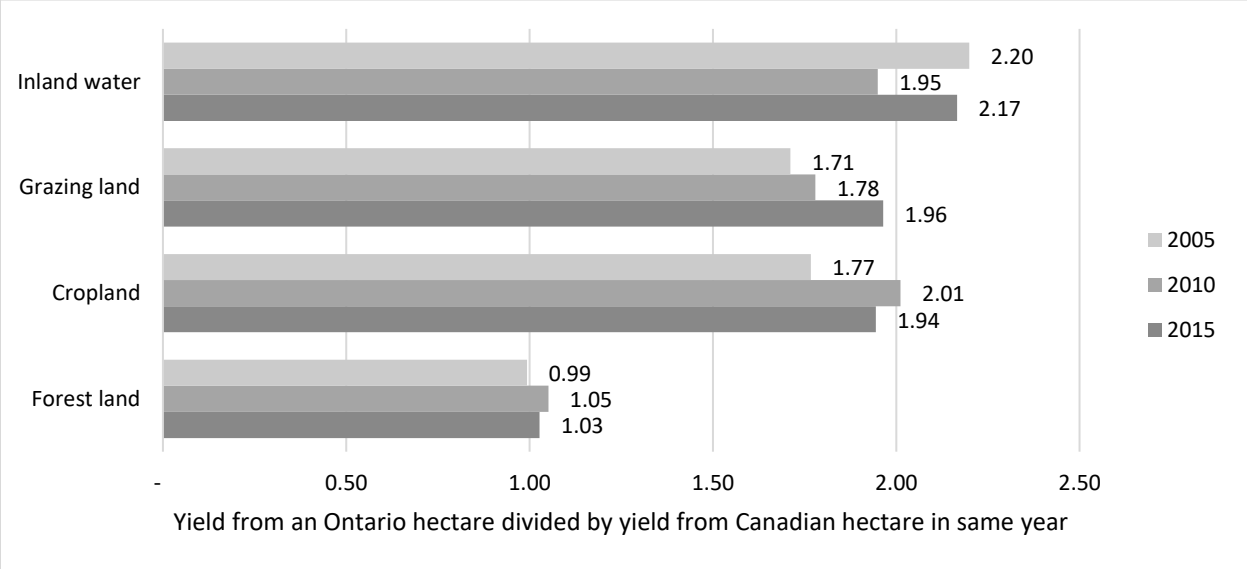
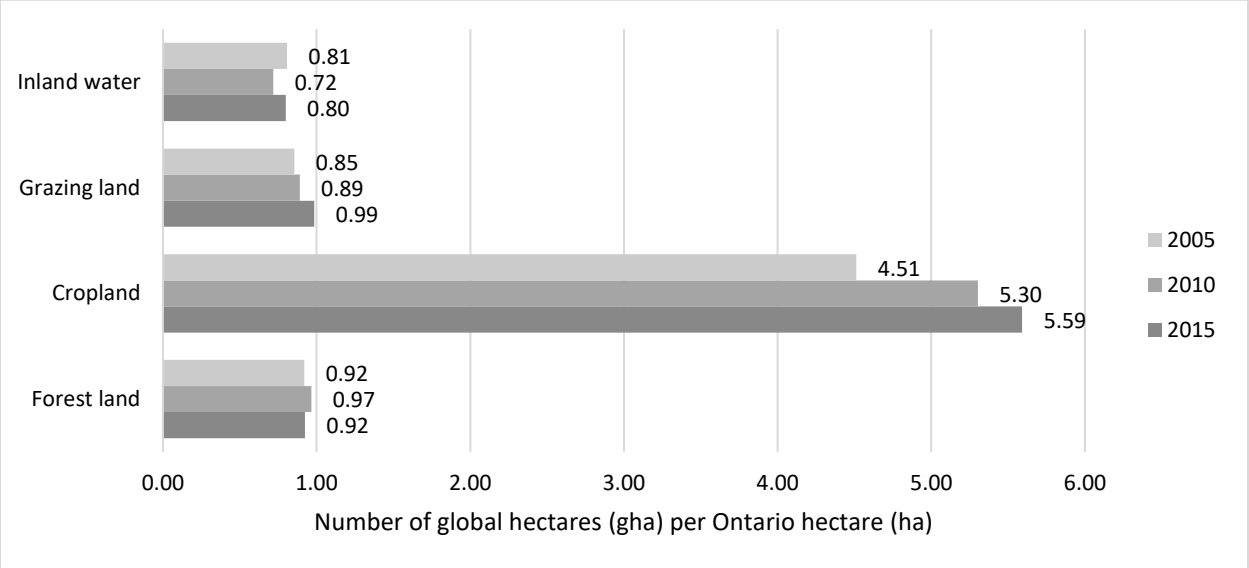


Figure 9 presents trends in Ontario yields relative to the average yield across Canada. These values correspond to a key "relative yield" parameter identified in the technical appendix. Changes in relative yield reflect the combination of changes in Ontario yields

and any changes in Canadian yields. Inland waters in Ontario yielded twice the mass of fish per hectare than were yielded from across Canada. Forest land yielded about the same volume of forest products per hectare in Ontario as per hectare across Canada. Cropland in Ontario yielded 94% more crops per hectare than cropland across Canada.

Figure 10 presents the number of global hectares provided per hectare of land or water in Ontario. These values correspond to the multiplication of several key parameters identified in the technical appendix, including relative yield, inter-temporal yield (if applicable), and global equivalence. A value of 1 would signify that one hectare in Ontario provides the same yield as one (average) global hectare. Inland water, grazing land, and forest land in Ontario provide biocapacity below the global average, even though each provided yields above the Canadian average in 2015 (when comparing values to those from the previous Figure 9). Inland water and forest land trended somewhat constant over time, while grazing land increased, as did cropland. Ontario cropland yielded crops above the global average, with one hectare in 2015 yielded 5.59 global hectares. Ontario's 3.6 million hectares of cropland in 2015 provided 20.4 million global hectares of biocapacity.

Figure 10: Trends in Ontario yields relative to global average, equal to number of gha per Ontario ha.



Trends in inland water

Ontario's biocapacity of Fishing Grounds reflects the fish harvested from Ontario's lakes, rivers and streams, or fish cultivated in aquaculture in Ontario. With over 250,000 lakes covering 17% of the province's land mass, Ontario's abundant freshwater offers valuable ecosystem goods that can be appropriated by humans (Ontario Ministry of Natural

Resources, 2009) in addition to important ecosystem services that are less easy to appropriate, but still valuable. Ontario has no marine area within its boundary, so it had no marine biocapacity.

Based on freshwater commercial harvest and aquaculture data, Ontario's share of Canada's fish production amounted to 16,545 tonnes or 47% in 2015. In other words, Ontario contributed to nearly half of Canada's freshwater harvest that year. Ontario's total freshwater production remained constant in the years 2005, 2010 and 2015. Ontario's relative yield from inland waters in 2015 was 2.16, signifying that Ontario's fishing grounds yielded more than twice the fish consumed by humans as the average from all inland waters of Canada. Relative to the world average, Ontario's inland waters provided humans with 0.8 global hectares of biocapacity per hectare of inland water.

Trends in cropland

Based on the most recent and available Canadian census data, Ontario cropland covered 3,647,439 hectares in 2016. This was a 6.9% increase compared to total cropland reported in 2011 (Statistics Canada, 2017). This increase can be partially attributed to advancements in technology and agricultural practices, which decreased the need for idle ("summerfallow") lands to build up nutrient and moisture content in the soil (Statistics Canada, 2017).

In 2015, Ontario accounted for roughly 10% of all Canadian cropland area, which is comparable to the province comprising 10.7% of Canada's total landmass. However, these lands in Ontario yielded 20% of Canada's total crop production (in tonnes), which is proportionally significant. Ontario cropland was approximately 1.8 times more biologically productive than the average world hectare of cropland and 4.5 times more productive than the average hectare of all land types globally in 2015. Ontario's cropland biocapacity in 2015 was 16,502,054 global hectares, which was an increase over 15.6 million global hectares in 2010 and 13.9 million global hectares in 2005.

Trends in grazing land

In contrast to cropland, grazing land area declined between 2011 and 2016 according to Statistics Canada agricultural census data (Statistics Canada, 2016). This trend can be partially attributed to a combination of declining cattle stock and improvements in grain crop prices that incentivize the conversion of pasture lands into cropland (Western Sarnia-Lambton Research Park, 2013). Grazing land forage crops, such as hay, improve soil

quality, reduce erosion, and improve moisture retention (Western Sarnia-Lambton Research Park, 2013), which may be lost upon conversion to cropland.

Ontario grazing land was more biologically productive than the average world hectare of grazing land but roughly 1% less productive than the average hectare of all land-use types globally in 2015. Globally, grazing land is less biologically productive than other land-use types, such as cropland or forest land, which produce more biomass per unit of area annually. Ontario grazing land yielded 96% more yield than the Canadian average in 2015, while each Ontario hectare was equivalent to 0.99 global hectares.

Trends in forest land

Forest land made up 52% of the area within Ontario's boundaries. This land provided the bulk of the province's biocapacity of forest products and carbon sequestration. From Ontario's Forest Resource Inventory, treed wetland and wetlands provide additional carbon uptake services (OMNRF, 2020). The Forest Resources of Ontario report notes that forest growth decreased by approximately 5% since 2011 (OMNRF, 2016b). This was due to the maturity of Ontario's forests, since greater annual growth occurs in younger trees and close to two thirds of Ontario's forests were in later successional stages. Only Jack Pine experienced growth, since most Jack Pine was in younger growth stages.

Ontario's forests yielded 3% more product than the Canadian average in 2015. However, the average hectare of Canadian forest yielded 0.71 times the biocapacity of an average global hectare of forest. Considering this, and considering the forest equivalence factor of 1.28, each hectare of forest provided 0.92 global hectares of biocapacity in 2015.

Changes in the Southern Ontario landscape from 2005-2015

Version 3 of the spatial data package SOLRIS (OMNRF, 2019) includes information about land-cover and land-use changes from 2000-2015. Changes are categorized as happening in one of several periods: either the period of 2005/2007 to 2009/2011, or 2009/2011 to 2014/2017. Table 6 presents an integrated synthesis of changes, aggregated into categories that matched to classes of biocapacity. During this period, 20,232 hectares of built-up land were gained by conversion from other land types, while 802 hectares of built-up land were lost to other land types from 2005 to 2015. Built-up land includes a small portion of pervious areas, some of which changed to forest land (1 ha) or cropland (13 ha). Shaded diagonal cells indicate a change within the same (aggregated) category; for example, a change in one type of built-up land to another type of built-up land.

Table 6: Landscape changes in hectares (ha) across Southern Ontario from 2005-2015.

Change from type (below) to type (in right columns)	Built-up land	Extraction	Forest land	Cropland	Undifferentiated	Inland water	Wetland	SUM ha lost
Built-up land	1,445	41	1	13	743	5	0	802
Extraction	53	22	1	94	1,192	258	8	1,605
Forest land	1,652	940	5	2,725	7,285	10	33	12,645
Cropland	3,242	946	0	23	5,438	76	4	9,708
Undifferentiated	14,456	1,958	14	476	844	81	7	16,990
Inland water	6	135	0	8	116	1	47	312
Wetland	823	1,070	0	2,096	6,269	20	298	10,279
SUM ha gained	20,232	5,090	16	5,412	21,043	449	99	52,340

Overall, the southern Ontario landscape was more built-up in 2015 than it was in 2005, mostly from 14,456 hectares of land that were previously "undifferentiated". SOLRIS metadata (OMNRF, 2019) identifies undifferentiated land to include other agricultural uses such as orchards and vineyards, perennial crops, land that has not been tilled in over ten years, as well as greenspaces adjacent to roadways, electric transmission corridors and urban thickets and openings in forests. In general, forests and wetlands and cropland transitioned to undifferentiated land, while undifferentiated transitioned to built-up.

Figure 11: Visualization of landscape changes across Southern Ontario from 2005-2015.

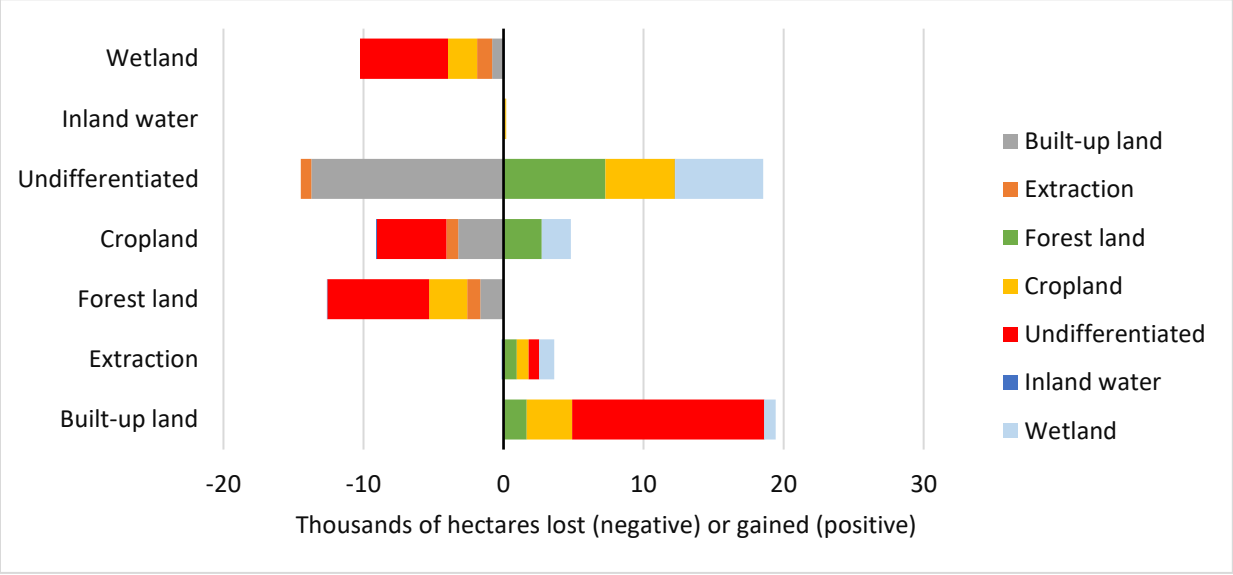


Figure 11 visualizes the data presented in Table 6 with each bar showing reductions in coverage to the left of zero and gains in coverage to the right. Each bar of loss and gain is colour-coded to identify where the gain was from, or what the land was lost to. For example, wetlands lost most of their 10,279 ha to "undifferentiated" (6,269 ha) and gained most of their 99 hectares from inland water (47 ha) and forest land (33 ha).

Table 7: Changes in Southern Ontario biocapacity from 2005-2015, aggregated by land use/type.

		Biocapacity (gha) gain (loss if negative) as the result of change		
	Ha gain (loss)	to...	from...	to and from...
Built-up land	19,430	-55,526	1,904	-53,622
Extraction	3,485	-11,469	3,667	-7,801
Forest land	-12,629	-21	21,223	21,202
Cropland	-4,295	0	-40,844	-40,844
Undifferentiated	4,053	12,210	-39,041	-26,830
Inland water	137	-283	95	-188
Wetland	-10,180	-76	23,625	23,550
			All changes	- 84,534

Table 7 presents the consequences on biocapacity of landscape changes within Southern Ontario from 2005-2015. Negative values indicate a loss of biocapacity while positive values indicate a gain. All gains or losses in hectares were converted to global hectares using the same parameters (of relative net primary productivity, yield factors, and equivalence) used throughout this report except for built-up land, which was assigned a yield of zero. Consistent with the rest of this report, undifferentiated land was assumed to have biocapacity equal to 32% of the value of cropland plus 20% of the value of grazing land plus 48% of the value of grassland. Parameters for forest land and wetland were derived as an area-weighted sum of their components in the Mixedwood Plains (dense forests and sparse forests, and peat fens and bogs and other wetlands, respectively). The most significant loss of biocapacity was from the net gain in built-up land. The net gain of 19,430 hectares of built-up land came at the expense of giving up 53,622 global hectares of biocapacity. All changes combined resulted in Southern Ontario having 84,534 fewer global hectares of biocapacity, which previously would have supported cropland, wetlands (providing wetland carbon-uptake) and forests (providing products or carbon uptake).

Comparing Ecological footprint and biocapacity in Ontario and beyond

Ecological Footprint and biocapacity are provided in global hectares so that they may be compared to each other, with Ecological Footprint measuring humanity's demand for biocapacity. This comparison can inform measures of human pressures on local and global landscapes, and their biodiversity. This comparison can also inform measures of sustainability. A necessary condition of sustainability is that human demands on the biosphere should not exceed the biosphere's capacity to meet them on an ongoing basis. This implies that the Ecological Footprint should be no greater than biocapacity at a global level. This is a necessary but not sufficient condition for sustaining humanity's metabolic relationship with the planet and its biodiversity. This concept is more complicated when applied to a country and especially to a province, such as Ontario, since it trades with the world. Nevertheless, the comparison helps to understand the global significance of consumption in Ontario, which puts pressures upon global biodiversity from the use of lands for food, fibres, materials, fuels, and sequestration.

Figure 12: Ontario Ecological Footprint versus biocapacity, in millions of global hectares.

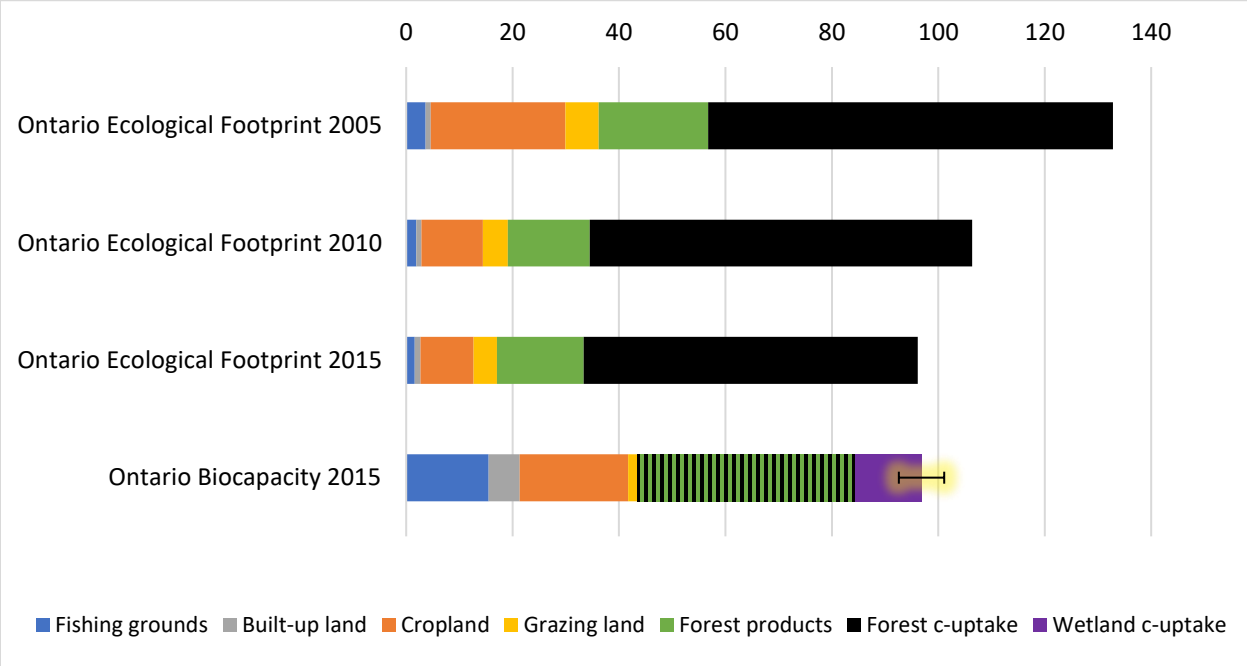


Figure 12 compares the Ecological Footprint of consumption in Ontario, from 2005 to 2015, with the biocapacity of lands and waters in Ontario in 2015. Forest biocapacity is labelled as a striped combination of green (for forest products) and black (for forest carbon uptake) since forests have the capacity to products or carbon uptake. Wetland carbon-uptake biocapacity is included as a purple bar which has the capacity to support the carbon

uptake component of the footprint (coloured black). Wetland biocapacity added enough biocapacity to bring its total up to Ontario's Ecological Footprint of consumption in 2015. This means that in 2015 Ontario's consumption required global biocapacity equivalent to the biocapacity provided by all lands and waters within Ontario. If wetlands not been considered as biocapacity, Ontario's footprint would have been 14% larger than biocapacity in that year. Wetland biocapacity was calculated using the midpoint of a range of sequestration rates from the cited literature (referenced in Table 17). Applying these ranges to the calculation of wetland biocapacity resulted in a range of plus or minus 34% of its central value. For this reason, the figure includes a 34% error bar for the wetland carbon-uptake component.

In 2015 the cropland component of Ontario's footprint was less than cropland biocapacity, reflecting the high productivity of cropland relative to domestic demand. Despite the large amount of forest biocapacity in Ontario, it was insufficient to support all the forest products consumed plus the sequestration of anthropogenic carbon emissions. Although the footprint's forest carbon uptake component declined since 2005, it was still greater than all forest biocapacity within Ontario. Built-up land biocapacity was significantly larger than Ontario's Ecological Footprint of consumption. This confirms that Ontario's landscape was more built-up than would otherwise be needed to support its consumption.

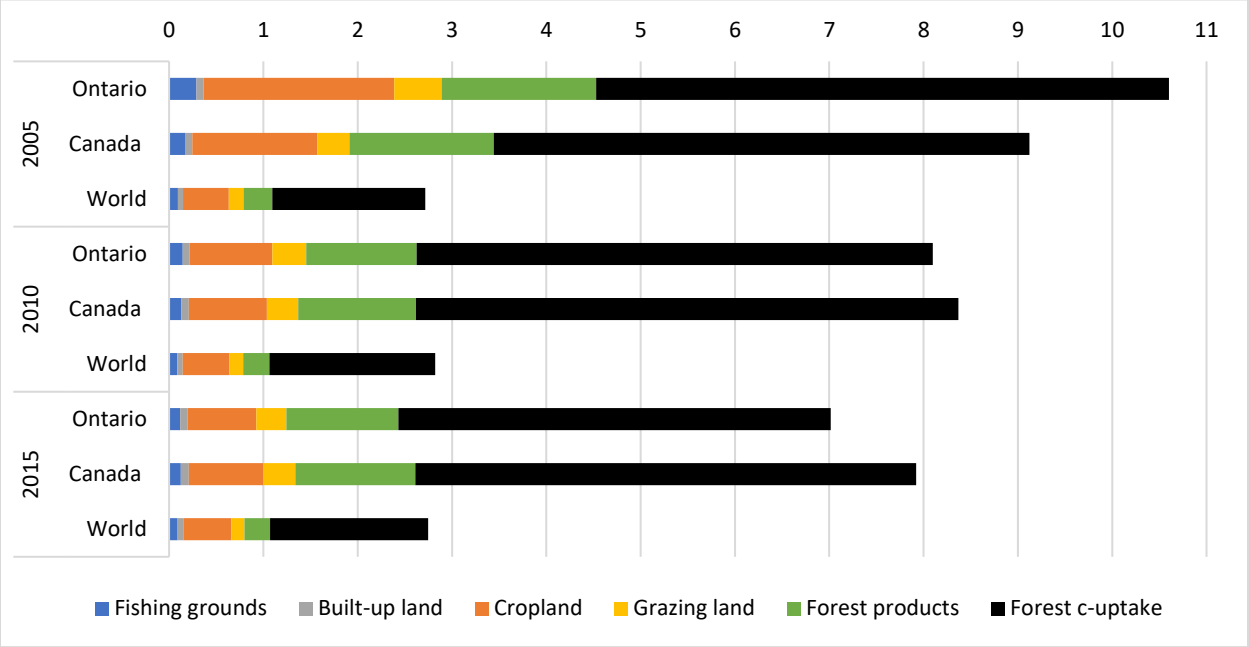
One important concept to keep in mind is that the Ecological Footprint and biocapacity are "flow" indicators that account for demand and supply within a period of a year. There is no corresponding accounting for an accumulation of flows over time to affect changes in an underlying "stock" of ecosystem resilience. In other words, any overshoot (or undershoot) of an Ecological Footprint relative to biocapacity does not debit (or credit) an underlying stock of ecosystem resilience. For this reason, results in this report should be considered along with other measures and trends related to stocks and their resilience. Similarly, results should be considered with agricultural insights about the quality of agricultural soils used for croplands and grazing lands. Results should also be considered along with other global measures and measurement systems that focus on humanity's metabolism of non-renewable minerals and emissions beyond carbon, all of which also affect biodiversity.

Ontario's Ecological Footprint in a Canadian and Global context

Figure 13 compares Ontario's Ecological Footprint on a per capita basis to the same for Canada and the world. From 2005 to 2015, Canada's Ecological Footprint declined in each 5-year period but at a lesser amount than the decline in Ontario's footprint. In all years, the

Ecological Footprint of consumption in Ontario and Canada were significantly higher than the global average which was about 2.7 gha.

Figure 13: Ontario Ecological Footprint compared to Canada and the world, in gha per capita.

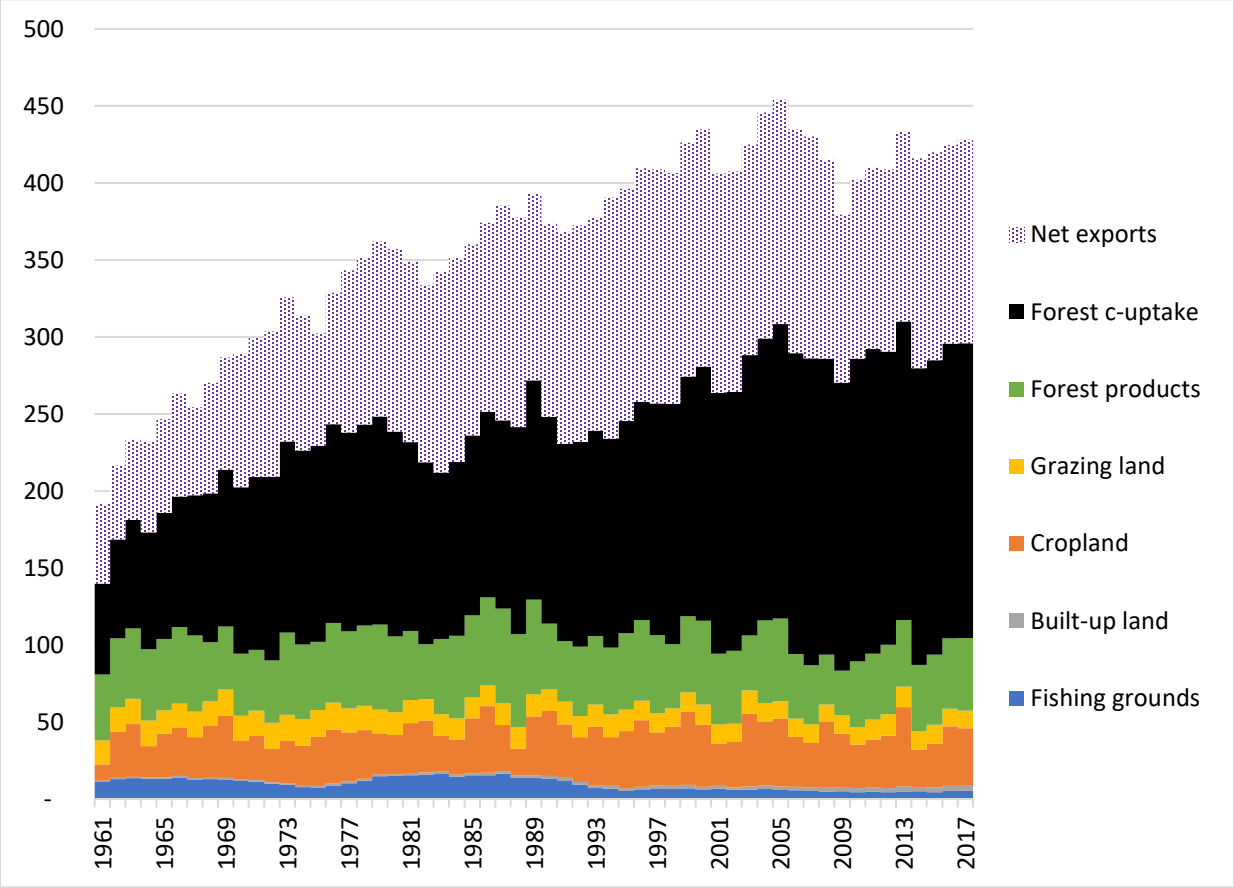


One notable change that took place in Ontario from 2005 to 2015 was a reduction in the carbon intensity of electricity, due to a phasing out coal-fired electricity generation. By 2015, electricity in Ontario was produced with 80% less carbon emissions than were produced per unit of electricity in 2005 (Ontario Ministry of Energy, 2017). This change accounted for about a fifth of the reduction in the forest carbon uptake component. Had this change not occurred, the forest carbon uptake component would have been about 5% greater in 2015 using the same emission parameters that existed in 2005. Conversely, if Ontario had phased out coal earlier, such that electricity-generated emissions in 2005 matched 2015 levels, the carbon component in 2005 would have been over 5% lower.

Figure 14 presents Canada's Ecological Footprint, by component of consumption and with the footprint of net exports. The National Ecological Footprint and Biocapacity Accounts present footprint data for national production and consumption. The Ecological Footprint of consumption is equal to the footprint of production, plus the footprint of all imports, minus the footprint of all exports. In each year (since 1961) the Ecological Footprint of exports from Canada exceeded the Ecological Footprint of imports into Canada. Canada exported footprint-intensive goods and services, and imported goods and services with a relatively smaller footprint. Therefore, in each year there was a positive footprint of *net*

exports (derived as the footprint of exports minus the footprint of imports). This component of net exports is stacked on top of the other components in the figure.

Figure 14: Canada's Ecological in millions of global hectares (gha), by component of consumption in Canada, plus the footprint of net exports (footprint of exports - footprint of imports).



In 2015, the Ecological Footprint of all goods and services produced in Canada was 420 million gha, while the Ecological Footprint of goods and services consumed in Canada was 285 million gha. Canada's Ecological Footprint of production was 47% greater that its footprint of consumption. Considering the monetary value of trade flows, each dollar of exports from Canada had about twice the footprint as each dollar of imports. Most of this related to the carbon intensity of exports, followed by the net export of forest products, followed by the next exports of crops. A similar pattern should be expected for Ontario during the period of 2005-2015 if not also before and after: Ecological Footprint *of production* in Ontario was likely much larger than Ontario biocapacity in each year.

Ecological Footprint in Ontario and Canada should be considered in a global context. Ontario's per capita Ecological Footprint (of consumption) in 2015 ranked 12th highest in

the world compared to other countries, with Canada in sixth place. Table 8 lists all 11 countries that had a larger footprint than Ontario.

Table 8: Ontario's rank among countries with the largest Ecological Footprint per capita in 2015.

Rank	Country	Ecological Footprint gha per capita
1	Qatar	14.58
2	Luxembourg	12.76
3	United Arab Emirates	9.54
4	Kuwait	8.44
5	United States of America	8.07
6	Canada	7.92
7	Bermuda	7.91
8	Mongolia	7.32
9	Denmark	7.15
10	Trinidad and Tobago	7.11
11	Estonia	7.03
12	Ontario	7.02

Figure 15: Global Ecological Footprint divided by global biocapacity in same year, showing overshoot.

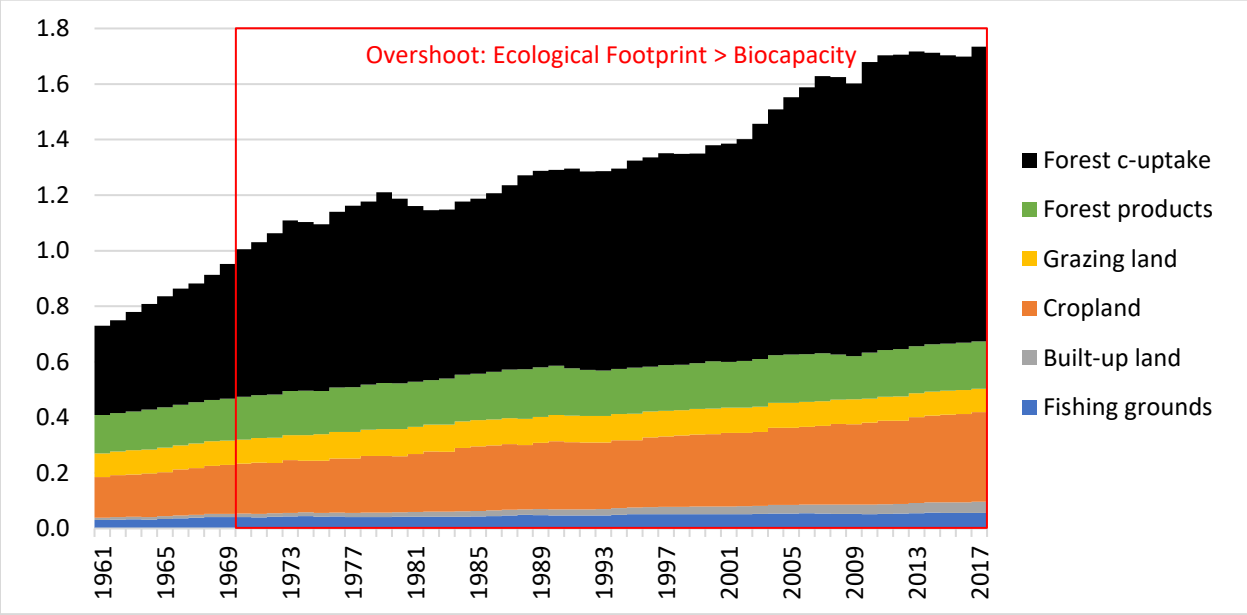


Figure 15 presents the growth of humanity's Ecological Footprint since 1961 as a ratio of footprint to biocapacity in each year. A value above 1 therefore means that footprint overshot biocapacity in that year. Since 1970 the Ecological Footprint of humanity has exceeded biocapacity in each year, with 70% overshoot in 2015. Globally, the world has

grown its demand for forest carbon uptake the most, reflecting growth in global carbon emissions. Lands needed for forest products and grazing land remained more constant over time. Built-up land was always the smallest component, but its share of the total grew. The shape of the trend since 1961 reveals significant global events, including the oil crisis of the mid-1970s, the US savings and loans crisis of the early 1980s, the dissolution of the former Soviet Union, the Asian financial crisis, and the global financial crisis. All led to short-lived absolute reductions, and all were followed by a rebound of a growing footprint.

Ontario biocapacity in a Canadian and global context

Comparisons between biocapacity in Ontario and Canada and other countries could only be made for standard components, without including this report's estimate of Ontario's wetland biocapacity. Excluding wetland biocapacity, Ontario had 84.3 million global hectares of biocapacity in 2015, which represented 16% of Canada's 543 million hectares of biocapacity. Compared to other nations, Ontario would rank 23rd in the world in 2015. In that year, Canada ranked fifth in the world, behind Brazil (in first place), China, United States of America, and the Russian Federation. Biocapacity can also be expressed in global hectares per capita. In 2015, Ontario's biocapacity per capita was 6.15 gha, which is less than half of the per capita measure for Canada of 15.16 gha, while also being almost four times the global per capita value of 1.61 gha. Figure 16 illustrates this comparison on a per capita basis and Figure 17 compares the same data as a proportion of the total.

Figure 16: Ontario biocapacity per capita, compared to Canada and world, in gha in 2015.

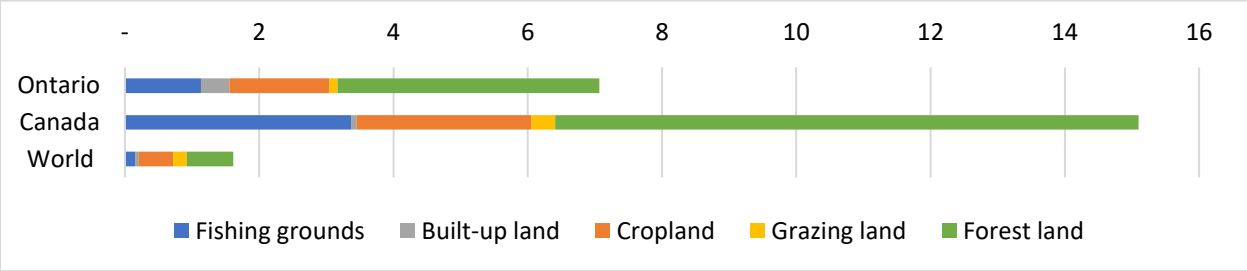
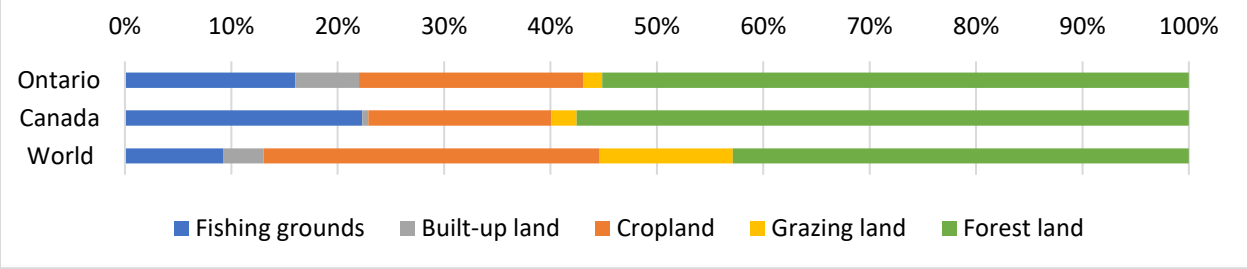


Figure 17: Proportion of total biocapacity in 2015 by category, in Ontario, Canada and world.



Conclusions

This report describes the data and methods used to derive the Ecological Footprint of consumption in Ontario, in 2005, 2010, and 2015, and the biocapacity of lands and waters within Ontario. Ontario's Ecological Footprint of consumption was the area of the planet needed to generate Ontario's consumption of food and fibres and forest products, plus Ontario's use of lands for settlements and infrastructure, plus the sequestration of anthropogenic carbon emissions attributed to goods and services consumed in Ontario. This was derived by a Consumption Land Use Matrix that related consumption of goods and services to their need for fishing grounds, built-up land, cropland, grazing land, forest products, and forest carbon uptake. Results were calibrated using national statistics about household expenditures, consumer prices, energy and emissions data, and multi-regional coefficients about global supply chains.

Ontario's Ecological Footprint of consumption declined from 132.8 million gha in 2005 to 106.4 million gha in 2010, to 96 million global hectares in 2015. This was a decline of 34%. Canada's Ecological Footprint of consumption also declined, by 13% during this period, but the Ecological Footprint of humanity's consumption increased by 14%. On a per capita basis, Ontario's Ecological Footprint in 2015 was 7 gha per person, which was smaller than the Canadian value of 7.9 gha. From 2005 to 2015, Ontario's Ecological Footprint declined even as its population increased. Nevertheless, Ontario's footprint on a per capita basis was high by global standards, ranking 12th among global nations in 2015.

Ontario's Ecological Footprint of consumption in 2015 was almost equal to Ontario biocapacity of 96.8 million gha. This total includes 12.5 million gha of wetland carbon uptake that was derived as a methodological innovation for this report, since it was not included in the National Ecological Footprint and Biocapacity Accounts. Rates of wetland carbon uptake, by type of wetland and ecozone in Ontario, were derived from published Ontario field research. Standard errors from the cited research about wetlands imply that total biocapacity was within a range of plus or minus 4% in 2015. Therefore, Ontario's Ecological Footprint of consumption in 2015 was within a range of being 4% larger than biocapacity or 5% smaller.

Ontario's lands and waters provided biocapacity at levels that tended to be above the Canadian average and below the global average, on a per-hectare basis. Built-up land in Southern Ontario grew from 2005 to 2015 out of the loss of 84,534 global hectares of biocapacity that previously would have supplied cropland, forest products, forest carbon uptake, and wetland carbon uptake. Nevertheless, Ontario's global demand for cropland was

within Ontario's cropland biocapacity. In contrast, Ontario's demands on forests, for products and for sequestration of anthropogenic carbon emissions, exceed the biocapacity provided by forests in Ontario, despite the significant area of forests in Ontario. Although Ontario's footprint related to carbon emissions declined since 2005, it was still too large to be sustained by biocapacity in Ontario.

This report presented Ontario's footprint on a consumption basis. The Ecological Footprint of consumption is equal to the footprint of production plus the footprint of all imports minus the footprint of all exports. Since 1961, Canada's Ecological Footprint of production has been larger than its footprint of consumption because Canada's exports have been more footprint intensive than its imports. Most of this relates to the carbon intensity of exports, followed by the net export of forest products, followed by crops. In 2015, the footprint of production was 47% larger than the footprint of consumption in Canada. A similar pattern should be expected for Ontario during the period of 2005-2015 if not also before and after: Ecological Footprint *of production* in Ontario was likely much larger than Ontario biocapacity in each year. This gap in Ontario would count towards one or more of its trading partners having a footprint of production below consumption.

Solving the global challenge of conserving biodiversity and living within the Earth's carrying capacity requires accounting for biocapacity and its use by humans. Various measures and measurement systems have been used to quantify carrying capacity and its use by humans, with the most comprehensive being Ecological Footprint and biocapacity. Both can be compared to inform human pressures on local and global landscapes, and their biodiversity. This comparison can also inform measures of sustainability. A necessary condition of sustainability is that human demands on the biosphere should not exceed the biosphere's capacity to meet them on an ongoing basis. This implies that the Ecological Footprint should be no greater than biocapacity at a global level. Unfortunately, the footprint of humanity has overshot biocapacity in every year since 1970. Fortunately, Ontario's 10-year decline in its footprint of consumption is a trend in the right direction. Hopefully this trend will continue and will become the global norm as the world seeks to achieve net zero carbon emissions by 2050. Such a goal implies achieving a global Ecological Footprint within the limit of available biocapacity, such that annual anthropogenic emissions are fully sequestered alongside other competing uses of lands and waters to support human consumption and to reverse the global decline in biodiversity.

A1: Overview of Methods and Sources

Data in this report were derived in part from NFA 2021: the 2021 Edition of the of National Ecological Footprint and Biocapacity Accounts (York University and Global Footprint Network, 2020). This edition contains data for all nations from 1961 to 2017 and a global summation for the entire world. This edition was produced at York University by sourcing about 45 million rows of data from various global databases that report production and consumption on a national basis by year. A *Guidebook to the National Footprint and Biocapacity Accounts* (Lin et al, 2021) identifies sources. The resulting accounts for Canada were used as the basis for deriving Ontario's Ecological Footprint and biocapacity.

Methods in this report are compatible with the Ecological Footprint Standards (Global Footprint Network, 2009) and more recent methodological innovations including those published in Borucke et al. (2013) and more recent refinements from Lin et al (2018). The Ecological Footprint Standards guide the production of sub-national accounts including innovations that are often possible or necessary with sub-national data. Multi-Regional Input-Output Analysis (MRIO) was used to derive the Canada and Ontario Consumption Land Use Matrix (CLUM), which followed a common approach within the literature including a recent assessment of municipal-level footprints in Canada (Isman et al, 2018).

Prior to the present report, two previous reports estimated the Ecological Footprint of consumption in Ontario and the biocapacity of lands and waters within the province. The first assessment by Stechbart and Wilson (2010) derived Ecological Footprint for 2005 by developing a Consumption Land Use Matrix (CLUM) using Canadian Input-Output (IO) data tables. The second assessment by Zokai et al (2015) derived Ecological Footprint for 2010 and 2005 by developing a CLUM for 2010 and 2005 using Multi-Regional Input-Output (MRIO) data from the Global Trade Analysis Project (GTAP). That project integrated Canadian IO data with IO data from other countries, or regional aggregates, to generate a globally consistent economic model. This same MRIO approach was used anew in the present report to generate CLUMs for 2015, 2010, and 2005, using more a recent tenth edition of MRIO data from GTAP.

Table 9 identifies key methodological differences between this report and prior ones for Ontario. The current report's inclusion of biocapacity from wetlands in Ontario, together with updated landscape information, and a broader derivation of Ontario-specific yields, resulted in a more robust accounting than was possible in prior reports. Altogether, these methodological and data differences signify ongoing progress in the evolution of Ecological Footprint and biocapacity accounting.

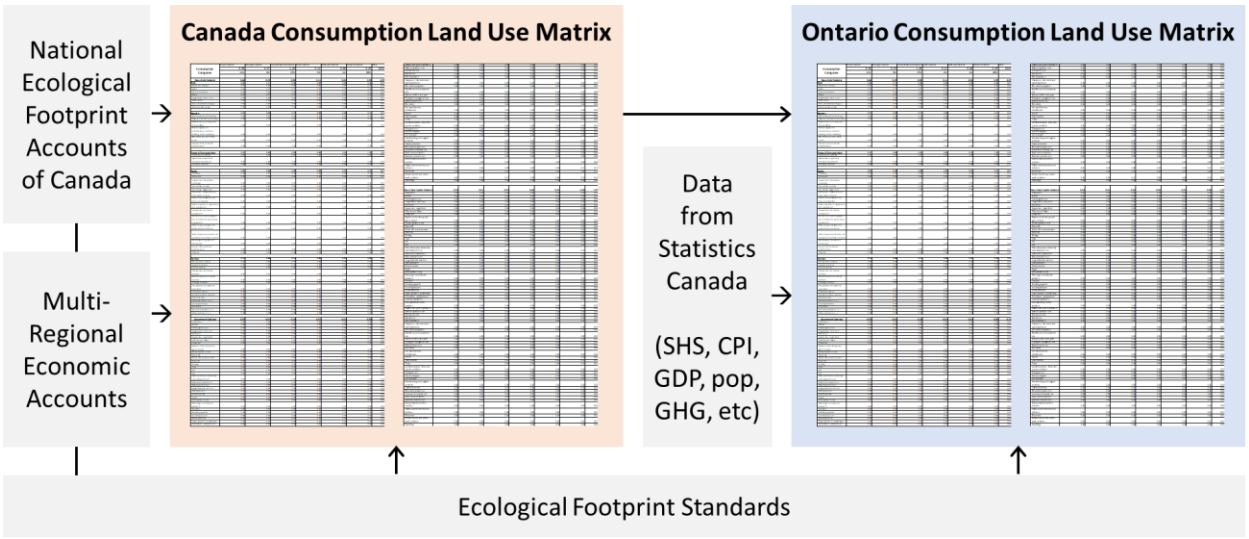
Table 9: Methodological differences with earlier reports.

Component	Report by Stechbart and Wilson (2010)	Report by Zokai et al (2015)	Present report
Year(s) of results	2005	2005, 2010	2005, 2010, 2015
National Footprint Accounts Edition	NFA 2008	NFA 2014	NFA 2021
Economic model	National IO (2003)	Multi-Regional IO: GTAP (version not specified, likely v7)	Multi-Regional IO: GTAP v10 (2019)
Source for area data (year)	Not specified	Not specified; believed to be PLC (2002)	SOLRISv3 (2015) OLCC v2 (2011)
Total area counted as biocapacity	82 million ha	71 million ha	106 million ha
Forest lands yields	From 2006 Ontario State of Forests Report	From 2011 Ontario State of Forests Report	From 2016 Ontario State of Forests Report, scaled to Net Primary Production by ecozone
Cropland yields	Provincial yield data for select crops		National yield data for Ontario and Canada for expanded list of crops plus orchards
Grazing land area	All grassland areas considered as grazing land		Area identified as grazing lands from Agricultural census
Grazing land yield	Equal to Canadian yield		National yield data for Ontario and Canada for Tame and corn fodder
Grassland areas	Not identified separately from grazing		Area of grasslands not counted as grazing
Freshwater (fishing grounds) yield	Ontario yield assumed to be equal to Canadian inland fisheries yield		Ontario-specific yield from all recorded commercial and aquaculture harvests from freshwater
Wetlands	(not included)		Included as biocapacity that provides terrestrial carbon sequestration

A2: Derivation of Ecological Footprint of consumption in Ontario

Ontario's Ecological Footprint was calculated using a "top-down" methodology to down-scale Canada's Ecological Footprint by apportioning each footprint component to consumption in Ontario. Figure 18 illustrates the approach, which integrated the consideration of differences between Ontario and Canadian consumption patterns from the Survey of Household Spending (SHS), differences in the relative price of goods and services consumed (CPI), and differences in the emissions (GHG) intensity of electricity generation. This scaling was applied to a Consumption Land Use Matrix (CLUM) of Canada that specifies the linkages, in a particular year, between footprint components and the consumption of goods and services that are recorded in economic accounts. This CLUM is a table with columns of footprint components and rows that detail the footprint attributable to a specific category of consumption of final goods and services.

Figure 18: Conceptual approach used to derive the Ecological Footprint of consumption in Ontario



Adjusting Canada CLUMs to 2015, 2010, 2005

Each CLUM allocates the consumption of good and services to three purposes: household consumption, government consumption, and gross fixed capital formation. Gross fixed capital formation is consumption used in the creation of durable infrastructure such as residential and commercial and industrial buildings, infrastructure for transportation and communications, and military equipment. The allocation of all consumption to these three purposes follows economic logic that these purposes are "final" consumption. All production by companies is deemed to be intermediate consumption because it becomes the final consumption of households or government, or final consumption if it is used to

form fixed capital. Gross means that fixed capital formation includes the repair of existing fixed capital, whereas net would mean only the creation of new fixed capital.

From an ecological economics perspective, gross fixed capital formation is the creation of "built capital" which is ultimately derived from "natural capital" being used with "human capital". Standard economic accounts still do not provide a systematic accounting for natural capital and its depletion, hence the need to create a CLUM to relate final consumption to lands (and water).

Canadian CLUMs were produced by the Global Footprint Network (GFN), by a method that used data from the Global Trade Analysis Project (GTAP) in its creation of a Multi-Regional Input-Output Analysis (MRIO) economic model. GTAP integrates Canadian Input-Output (IO) data with IO data from other countries, or regional aggregates, to generate GTAP as a globally consistent economic model that can allocate Canada's final demand, including all of its imports, to the inputs used by various economic sectors to produce final outputs.

The GTAP project has produced different versions of its flagship model, which rely on different vintages of global data and different methodologies and detail. GTAP version 10 provides global data that captures global economic inter-relationships that existed in 2014, 2011, 2007, 2004. This was used by Global Footprint Network to produce a Canada CLUM for 2014, 2011, and 2004, with each of these supplied to the research team for the present report. Data from the 2021 edition of the National Ecological Footprint and Biocapacity Accounts (York University and Global Footprint Network, 2020) were used to linearly interpolate the CLUMs by one year. Therefore, if Canada's carbon component of the footprint was 1% greater in 2015 as compared to 2014, then that component of the 2014 CLUM was inflated by 1% to generate the 2015 value.

Deriving Ontario CLUMs from Canada CLUMs

To generate an Ontario CLUM from a Canadian CLUM, data were sourced from Statistics Canada (2020): the Survey of Household Spending (SHS) (Statistics Canada Table 11-10-0222-01), the Consumer Price Index (CPI) for Canada and Ontario (Statistics Canada Table 18-10-0005-01), CPI basket weights for Canada and Ontario (Statistics Canada Table 18-10-0007-01), Gross Domestic Product by expenditure and income (Statistics Canada Table 36-10-0222-01), greenhouse gas emissions by sector and activity (Statistics Canada Table 38-10-0097-01), and population of Canada and Ontario (Statistics Canada Table 17-10-0005-01). Emissions data were also sourced from Environment and Climate Change Canada (2020).

Data from the Survey of Household Spending was reclassified to match the categorization of final consumption spending in the CLUMs, which follow the United Nations Classification of Individual Consumption According to Purpose (Department of Economic and Social Affairs, 2018), which are food, shelter, transportation, goods, and services. Next, household expenditures for each group were expressed per capita (EQ1) since the CLUM expresses Ecological Footprint in this matter.

EQ1: **Expenditure/capita** = Expenditure/Average Household size

To determine the price changes for both Canada and Ontario in each category, Consumer Price Index (CPI) data for each consumption category and their basket weight were collected. As with SHS data, each CPI category was related to the CLUM categories (EQ2). In many cases, additional CPI data points were needed to be developed to match the CLUM categories. This was done by re-weighting each using information about the CPI basket weights for each item.

EQ2: **Adjusted CPI** = $\sum$ ($Item_X$ / Total Basket of category) * CPI_X

Next, a scaling factor was derived for Ontario households to capture the extent to which Ontarians consumed more or less of the same good or service than average Canadians (EQ3). Scaling involved dividing expenditure/capita (by consumption category) in Ontario by the same consumption category in Canada. This scaling also needed to account for differences in per-unit costs of goods and services in Ontario relative to Canada. Thus the CPI of each good or service consumed in Ontario was divided by the CPI of the same for Canada.

EQ3: **Scaling Factor for Household** = ($Expenditure_{ONx}$/$Expenditure_{CANx}$)/(CPI_{ONx}/ CPI_{CANx})

The CLUM portions related to government consumption and gross fixed capital formation were scaled by per capita GDP within Ontario devoted to gross fixed capital formation relative to the same for Canada (EQ4 and EQ5). We used real chained Gross Domestic Product by Income and Expenditure to avoid introducing inflationary biases.

EQ4: **Scaling Factor for Gross Fixed Capital** = Ontario GDP per Capita of Gross Fixed Capital/Canada GDP per Capita of Gross Fixed Capital

EQ5: **Scaling Factor of Government** = Ontario GDP per Capita of Government/Canada GDP per Capita of Government

The CLUM identifies the consumption of electricity, natural gas, and other fuels within households. Even after scaling Ontario's consumption of this energy to reflect Ontario-versus-Canada differences in household expenditures, household sizes, and consumer prices, it was necessary to apply an additional Energy Factor to account for significant differences in emissions from energy produced in Ontario relative to the Canadian average.

When Ontario households consume electricity (produced in Ontario) they consume electricity that has fewer emissions per unit of electricity than the average across Canada. Emissions are slightly different in Ontario than the Canadian average for the combustion of natural gas and other fuels, so these data were also integrated. Because electricity consumption was aggregated with natural gas and other fuels, we needed to disaggregate this bundled consumption data into its constituent parts, based on the relative importance of each in the basket used to generate CPI in Ontario and Canada. Thereafter, we scaled each form of energy based on differences in emissions per population in Ontario relative to Canada (EQ6), and then reassemble this into an aggregate Energy Factor (EQ7).

EQ6: **Energy$_x$Emissions** = (Ontario Energy$_x$Emissions / pop) / (Canada Energy$_x$Emissions / pop)

EQ7: **Energy Factor** = ∑ ((spending on Energy$_X$/Total energy spending) x Energy$_x$Emissions)

After deriving all scaling factors, we applied each, where relevant, to the Canadian CLUM **(EQ6)** which then meant that the Ecological Footprint for Ontario in that year was the sum of all of the footprint components **(EQ7).**

EQ8: **ON CLUM** = ∑ CAN Item$_x$ * Scaling Factors$_x$

EQ9: Ecological Footprint$_{ON}$ = Carbon Footprint + Crop Footprint + Forest Footprint + Grazing Footprint + Fishing Ground Footprint + Built-up Land Footprint

Abridged versions of the resulting Ontario CLUMs for 2015, 2010, 2005 are in Appendix A5-A7. the full version of the CLUMs each contain about 200 rows.

A3: Derivation of Amalgamated Land Cover (ALC) for Ontario

An Amalgamated Land Cover (ALC) was generated to classify Ontario into one of several mutually exclusive land classes, at a resolution of 15 metres. This spatial layer was created using Geographic Information System (GIS) software to amalgamate the most recent spatial information about Southern Ontario with the most recent information about the rest of Ontario. All spatial data was sourced in February 2020 from the Ontario GeoHub provided by the provincial agency Land Information Ontario (gohub.lio.gov.on.ca).

ALC was built by amalgamating Ontario Land Cover Compilation (OLCC) version 2.0 (OMNRF, 2014) with Southern Ontario Land Resource Information System (SOLRIS) version 3 (OMNRF, 2019). OLCC was already derived from an amalgamation of three land cover databases: Provincial Land Cover 2000 Edition (PLC2000), Far North Land Cover version 1.4 (NFLCv1.4), and SOLRIS version 1.2 (OMNR, 2008). The OLCC inventory was used in the previous Ontario report (Zokai et al, 2015) and represents ecologically based land cover and change inventory for the entire province from 1991-2011 (OMNRF, 2014).

Since the publication of OLCC version 2 in 2014, SOLRIS was updated to version 3 with this latest version accounting for the landscape in between 2014 and 2017. SOLRIS version 3 also includes an inventory of changes to the landscape from the first edition of SOLRIS, thereby accounting for changes in between 2000 and 2015 that reflect both a correction of previous categorizations and actual changes in the landscape (OMNRF, 2019, p. 5). We therefore used this version to generate our ALC that more closely resembles Ontario in 2015 than OLCC. This amalgamation of the two spatial layers was possible using a raster mosaic tool that updated the OLCC v. 2.0 layer with data from SOLRIS v. 3.0 throughout its southern portion.

No pixels of land and water were double counted, but some categories of land from OLCC were no longer present in the ALC if they were replaced with updated SOLRIS data. Surprisingly some portions of the Great Lakes appeared to be missing in the source data from OLCC: a portion of Lake Superior adjacent to the Canada-USA border in the Ontario Shield ecozone, and a portion of Georgian Bay in that same ecozone and the Mixedwood Plains and a portion of Lake Huron south of Manitoulin Island adjacent to the Canada-USA border. This area sums to under 1% of the total area of Ontario and was also omitted in the prior Ontario Ecological Footprint and biocapacity assessment by Zokai et al. (2015).

Table 10: Ontario biocapacity classifications applied to Amalgamated Land Cover (ALC) derived from Ontario Land Cover Compilation v2 (OLCCv2).

ID	Description in OLCC v2	ALC Area (ha)	Allocation to Ontario Biocapacity class(es)
-99	Other	54,691	100% Unable to determine
-9	Cloud / Shadow	111,901	100% Unable to determine
1	Clear Open Water	14,453,250	100% Freshwater
2	Turbid Water	372,817	100% Freshwater
4	Mudflats	10,739	100% Freshwater
5	Marsh	228,874	100% Wetlands: Other
6	Swamp	9,087,465	30% Forest: Sparse + 70% Wetlands: Other
7	Fen	11,116,302	100% Wetlands: Peat Fens
8	Bog	14,157,933	100% Wetlands: Peat Bogs
10	Heath	67,122	100% Low Biocapacity
11	Sparse Treed	4,815,699	100% Forest: Sparse
13	Deciduous Treed	5,127,595	100% Forest: Dense
14	Mixed Treed	11,385,196	100% Forest: Dense
15	Coniferous Treed	12,977,437	100% Forest: Dense
16	Plantations - Treed Cultivated	0	100% Forest: Dense
17	Hedge Rows	0	100% Forest: Dense
18	Disturbance	8,594,089	100% Forest: Disturbed
25	Sand / Gravel /Mine Tailings / Extraction	46,570	100% Extraction
26	Bedrock	329,477	100% Low Biocapacity
27	Community / Infrastructure	303,789	100% Built-up
28	Agriculture and Undifferentiated Rural Land Use	456,081	30% Cropland + 23% Grazing land + 48% Grassland

Table 10 accounts for all the components of the ALC that were sourced from OLCC, while Table 11 accounts for all components sourced from SOLRIS version 3. All data within the ALC landscape was matched to "Ontario biocapacity classes" that we created as an intermediate relationship between all of Ontario's landscape and the categories of biocapacity within the National Ecological Footprint and Biocapacity Accounts. Relationships were established with the aid of detailed metadata documents from OLCC and SOLRIS to understand the source data and any caveats provided.

Some components of the landscape involve a mix of different elements, such as "tallgrass savannah" characterized as mix of grasslands and sparsely treed landscapes. Where vegetation cover was less than 25%, the component was characterized as "low biocapacity". Where tree cover indicated as a range, the average within the rage was

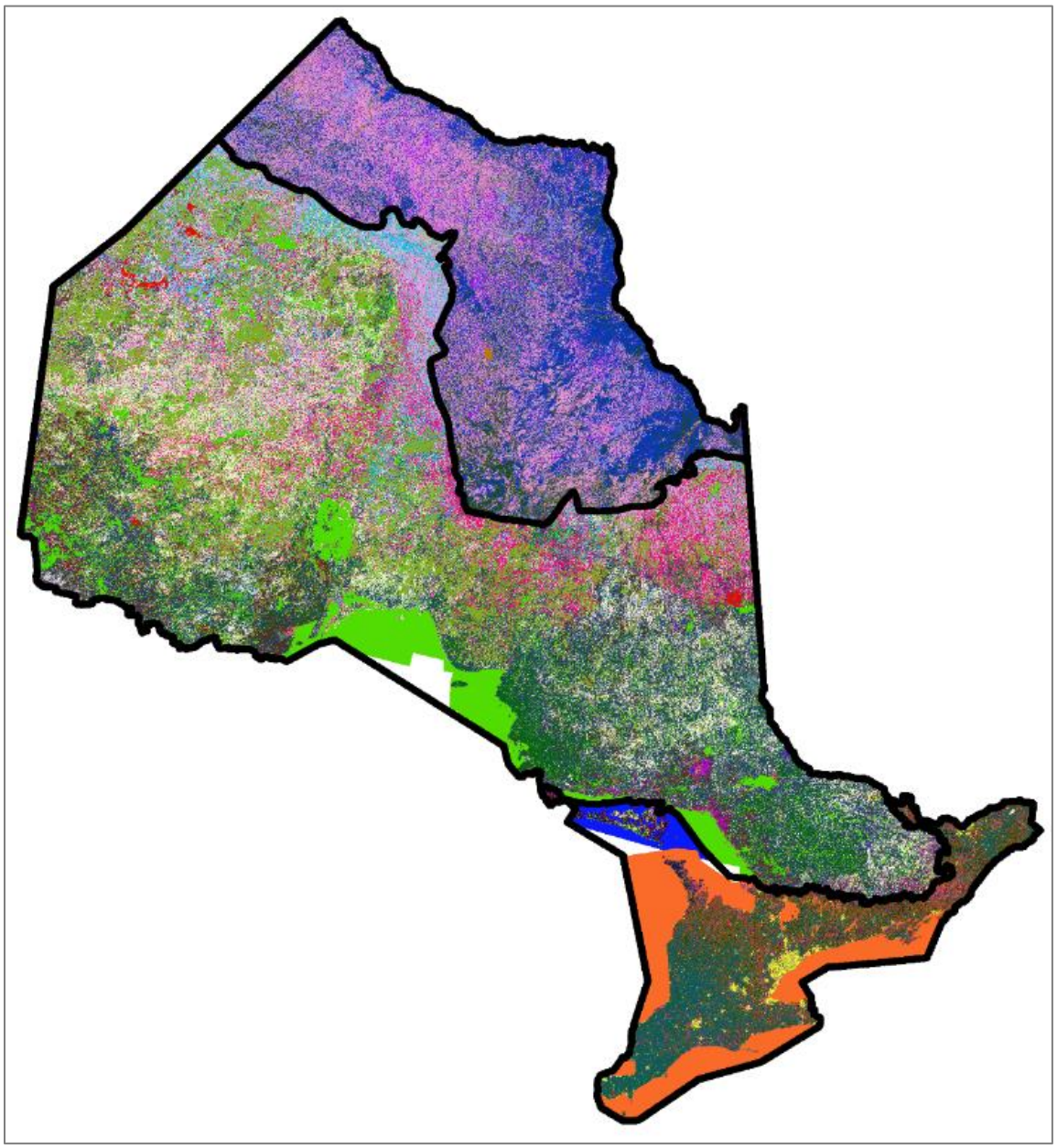
applied; e.g. tree cover less than 60% was coded as 30% sparse (as the average of 60 and zero). ALC components characterized as agricultural or undifferentiated were apportioned in such a way that the resulting areas matched the area of cropland and grazing land provided by the census of agriculture and its regional disaggregation.

Table 11: Ontario biocapacity classifications applied to Amalgamated Land Cover (ALC) derived from Southern Ontario Land Resource Information System v3 (SOLRIS v3).

ID	Description in SOLRIS v3	ALC Area (Ha)	Allocation to Ontario Biocapacity class(es)
11	Open Beach / Bar	1,415	100% Low Biocapacity
21	Open Sand Dune	698	100% Low Biocapacity
23	Treed Sand Dune	495	65% Low Biocapacity + 35% Forest: Sparse
41	Open Cliff and Talus	2,049	100% Low Biocapacity
43	Treed Cliff and Talus	126	60% Low Biocapacity + 40% Forest: Sparse
52	Shrub Alvar	699	80% Low Biocapacity + 20% Forest: Sparse
53	Treed Alvar	539	60% Low Biocapacity + 40% Forest: Sparse
64	Open Bedrock	7,955	100% Low Biocapacity
65	Sparse Treed	16,185	100% Low Biocapacity
81	Open Tallgrass Prairie	336	90% Grassland + 10% Forest: Sparse
82	Tallgrass Savannah	693	65% Low Biocapacity + 35% Forest: Sparse
83	Tallgrass Woodland	1,206	55% Grassland + 45% Forest: Dense
90	Forest	28,331	100% Forest: Dense
91	Coniferous Forest	250,410	100% Forest: Dense
92	Mixed Forest	406,160	100% Forest: Dense
93	Deciduous Forest	705,510	100% Forest: Dense
131	Treed Swamp	845,695	40% Forest: Sparse + 60% Wetlands: Other
135	Thicket Swamp	126,005	15% Forest: Sparse + 85% Wetlands: Other
140	Fen	8,323	100% Wetlands: Peat Fens
150	Bog	9,340	100% Wetlands: Peat Bogs
160	Marsh	170,530	10% Forest: Sparse + 90% Wetlands: Other
170	Open Water	4,600,054	100% Freshwater
191	Plantation - Tree Cultivated	88,137	100% Forest: Dense
192	Hedge Rows	56,299	100% Forest: Dense
193	Tilled	2,852,754	100% Cropland
201	Transportation	295,188	100% Built-up land
202	Built Up Area-Pervious	93,093	100% Built-up land
203	Built Up Area-Impervious	344,035	100% Built-up land
204	Extraction-Aggregate	24,138	100% Extraction
205	Extraction-Peat/Topsoil	1,431	100% Extraction
250	Undifferentiated	2,095,687	32% Cropland + 20% Grazing land + 48% Grassland

Some portions of Ontario provided ecosystem goods and services in 2015 that could not be appropriated by humans in a significant and sustainable way. These portions totalled 426,631 ha (0.4% of Ontario) and were characterized as "low biocapacity" and excluded from further consideration. Extraction amounted to a total of 72,139 ha (0.1% of the total landscape) and was also excluded from further analysis; these areas provide ecosystem goods through depletion and not on a regenerative basis, so they were also excluded from further consideration. Also excluded were portions that were characterized as "Cloud/Shadow" or "Other" totalled 166,592 ha (0.2% of Ontario).

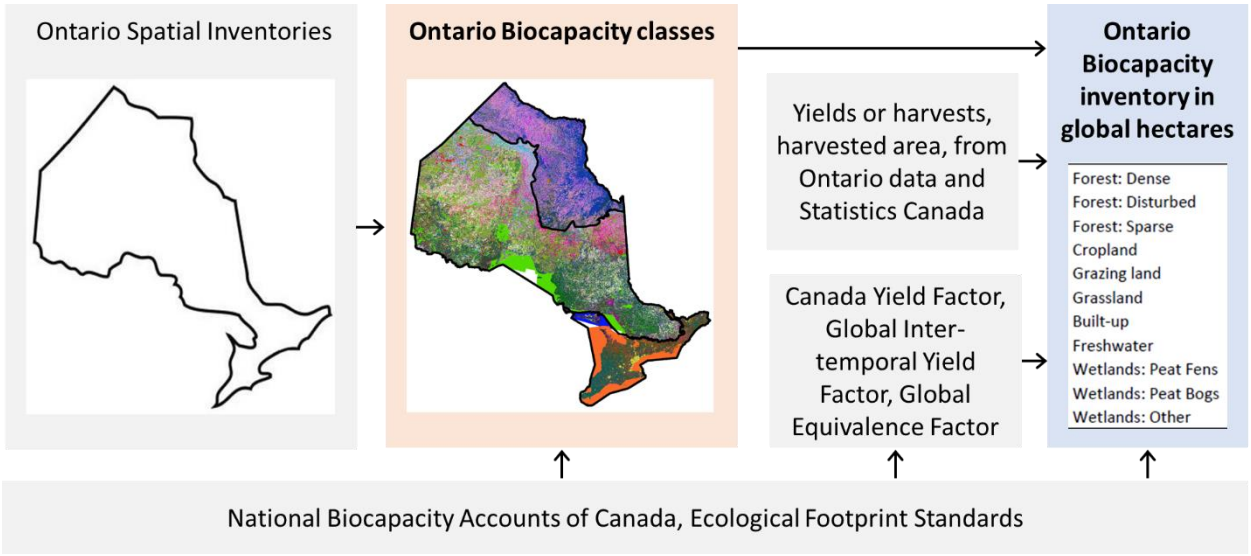
Figure 19: Amalgamated Land Cover of Ontario delineated by Ecozone boundaries.



The current report considers more biocapacity than prior Ontario assessments. Wetlands have never been included in the National Ecological Footprint and Biocapacity Accounts, yet their significance in Ontario warranted their consideration. Prior Ontario assessments from Zokai et al (2015) and Stechbart and Wilson (2010) excluded these portions of the landscape, with the result that almost one-quarter of Ontario's land area was excluded. The present analysis builds on these prior report's recommended to include them.

Once the ALC was created, it was clipped to the boundaries of Ontario's Ecozones, derived from a vector-based spatial layer from Ontario GeoHub. The resulting inventory of Ontario by ecozone is presented in Figure 19, with the Ecozone boundaries thickened for display purposes, and with different land cover classes represented by different coloured pixels. Thereafter, area data was applied to a suite of parameters including yield and equivalence to derive measures of biocapacity in global hectares as illustrated in Figure 20. These parameters are described in the next section.

Figure 20: Conceptual approach used to derive biocapacity in Ontario



A4: Derivation of biocapacity in Ontario

Biocapacity of each class of land or water in the Amalgamated Land Cover was derived by multiplying their area by several parameters identified below. Two of these parameters, ONT_rNPP and ONT_RY were derived from Ontario-specific data according to methods detailed later in this appendix. One parameter, CAN_YF, reflected Canadian data derived from NFA 2021. Two parameters, GLOBAL_IYF and GLOBAL_EQF reflected global data derived from NFA 2021. Multiplying these five parameters resulted in the conversion of Ontario hectares into global hectares. This method accounted for differences in land productivity in Ontario, relative to the average of the same class of hectares in Canada, relative to the average of the same classes across the planet, and relative to the equivalence between the global productivity of different classes of land. The resulting units of global hectares allow biocapacity in Ontario to be compared to biocapacity and Ecological Footprint, as per the methodology of Ecological Footprint and biocapacity accounting established in Borucke et al. (2013) and updated with new editions since then (Lin et al, 2018).

Mathematically, a global hectare (gha) was derived from an Ontario hectare (ha) as follows:

$$gha = ONT\_ha \times ONT\_rNPP \times ONT\_RY \times CAN\_YF \times GLOBAL\_IYF \times GLOBAL\_EQF$$

ONT_ha	Hectares in Ontario of a specific class of biocapacity, by ecozone
ONT_rNPP	Relative Net Primary Production (NPP) of forest or wetland, by ecozone (Only applied to forest or wetland biocapacity classes) = NPP of specific type of forest or wetland in ecozone / NPP of dense forest in Ontario Shield ecozone
ONT_RY	Relative yield of average hectare in Ontario compared to same in Canada = Ontario Yield / Canada Yield = Mass of harvest in Ontario / Area in Ontario harvested / Mass of harvest in Canada / Area in Canada harvested
CAN_YF	Canadian Yield Factor (from NFA 2021)
GLOBAL_IYF	Global Inter-temporal Yield Factor (from NFA 2021)
GLOBAL_EQF	Global Equivalence Factor (from NFA 2021)

Table 12: Parameters used to generate Ontario biocapacity in global hectares for the year 2015.

Ontario biocapacity Class	Related NFA classification	ONT_rNPP			ONT_RY	Parameters from NFA 2021		
		HBL	MWP	OS		CAN_YF	GLOBAL_IYF	GLOBAL_EQF
Forest: Dense	Forest	0.85	1.11	1.00	1.03	0.71	1.00	1.28
Forest: Disturbed		0.83	1.08	0.98				
Forest: Sparse		0.53	0.70	0.63				
Cropland	Cropland				1.94	1.19	0.97	2.50
Grazing land Grassland	Grazing land				1.96	1.09	1.00	0.46
Built-up land	Built-up land				1.94	1.19	0.97	2.50
Freshwater	Inland water				2.17	1.00	1.00	0.37
Wetlands: Peat Fens	(forest carbon)	0.32	0.42	0.38	1.03	0.71	1.00	1.28
Wetlands: Peat Bogs		0.50	0.65	0.58				
Wetlands: Other		0.28	0.37	0.33				

Table 12 details all parameters that were used to convert Ontario hectares to global hectares for each specific class of biocapacity. Wetlands do not exist as a class of biocapacity the National Ecological Footprint and Biocapacity Accounts but were included in this report (using methods and sources described later in this appendix). The carbon uptake of a hectare of Ontario wetland was converted to an equivalent of carbon uptake from a hectare of Ontario forest. Therefore, the ONT_RY and CAN_YF and GLOBAL_IYF and GLOBAL_EQF used for Ontario wetlands were the same as for Ontario forests. Areas within the ALC that were classified as "low biocapacity", "extraction", and "unable to determine" (which sum to 665,362 ha) were all assigned a global hectare of zero.

Biocapacity of forest lands

Forest lands provide biocapacity in the form of forest products, when harvested, and carbon sequestration when not harvested. Data on forest increment for 2015, 2010 and 2005 were sourced from the 2016 State of Forest Resources of Ontario (OMNRF, 2016a), along with forested area statistics to calibrate the classification of the area of various forest types in Ontario derived from the ALC land cover. This allowed a relative yield to be calculated, as the average forest yield in Ontario divided by the average Canadian forest yield, from NFA 2021. Average forest yield was based on the Current Annual Increment (CAI) for 2016, as published in the Forest Resources of Ontario 2016 report (OMNRF, 2016b). The CAI measured the volume of growth in a tree in a one-year period. The

average forest yield in Ontario was the sum of the hectares of each forest type, multiplied by its CAI and divided by the total forest area.

Table 13: Yield from Ontario's forests, 2005-2015, by provincial forest type (OMNRF, 2016b)

Provincial Forest Type	2005 CAI (m3/ha)	2010 CAI (m3/ha)	2015 CAI (m3/ha)
White Birch	1.32	1.2	1.1
Conifer Lowland	0.74	0.8	0.8
Conifer Upland	1.33	1.27	1.26
Mixedwood	1.56	1.5	1.44
Jack Pine	1.24	2.49	2.61
Poplar	1.52	1.51	1.43
Red and White Pine	1.43	1.36	1.27
Tolerant Hardwoods	1.61	1.52	1.4
Note: CAI is Current Annual Increment			

We assumed that 2016 data could be used to represent 2015, acknowledging that this was likely a conservative estimate given the trend of declining increments shown in the accompanying data from 2006 and 2011. The CAI data exclusively reflects the area in Ontario where forest management occurs, in the "Area of the Undertaking" (MNR-71) or AOU. The Whitefeather Forest (MNR-14), un-inventoried blocks of private land, and Wabikimi Provincial Park were not included. The CAI data was from Ontario's Forest Resources Inventory (FRI), a large-scale survey of the province's forests and wetlands based on LiDAR data, ground plots, information from local Forest Resources Inventory users, historical fire data, silviculture records, and soil information.

Table 14: Ontario Forest Yield based on AOU productive forest CAI for 2015.

Provincial Forest Type	CAI (m3/ha)	Area (ha)	CAI (m3/year)	Yield weighted by Forest Type (m3/ha)
White Birch	1.1	2,507,928	2,758,721	0.08
Conifer Lowland	0.8	7,587,958	6,070,366	0.18
Conifer Upland	1.26	7,662,009	9,654,131	0.29
Mixedwood	1.44	6,230,310	8,971,646	0.27
Jack Pine	2.61	2,803,176	7,316,289	0.22
Poplar	1.43	3,557,154	5,086,730	0.15
Red and White Pine	1.27	1,051,867	1,335,871	0.04
Tolerant Hardwoods	1.4	2,363,596	3,309,034	0.10
	Total	33,763,999	44,502,790	1.32

Biocapacity data presented thus far covered only a portion of the forested area of Ontario. The remaining forested areas made up nearly half of the province's forested lands and were classified in 2016 by using satellite data compiled by the Ministry of Natural Resources between 2002 and 2008 from Landsat 7 imagery and updates (OMNRF, 2016b). The present report connects these 2016 findings with OLCC and SOLRIS classifications of treed land using three classes of forest land to group lands outside of the CAI assessment: "forest", "forest disturbed", and "forest sparse".

Ontario's forest biocapacity was further refined by ecozone to account for varying levels of Net Primary Production (NPP) of biomass. This enabled the calibration of yields of forest products, or carbon sequestration, by ecozone. NPP of biomass is measured as a rate of carbon accumulated per area per unit of time. Ontario-specific measures were derived from the State of Ontario's Natural Resources – Forest Indicators (OMNRF, 2015) which reported modelled estimates of NPP for 2011 and 2016. We applied 2016 values to 2015.

Table 15 presents Net Primary Production (NPP) of forests by ecozone. Ontario reported that forests in 2016 were estimated to provide NPP of 1.61 tC/ha/year on average across all of Ontario (down from 1.77 in 2011). This Ontario-wide average was also equal to the value for forests on Crown land within the Area of the Undertaking; we therefore applied this value of 1.61 to forests within the Ontario shield since most of this forest land occurs within this Ecozone. Ontario reported a value of 1.79 tC/ha/year for private land; we applied this value to forests within the Mixedwood Plains since most private-land forestry exists within this Ecozone. This higher value reflects a longer growing season in the south enabling more accumulation of biomass. Ontario reported a value of 1.57 tC/ha/year for "northern boreal fire management zone" which we applied to disturbed forest within the Ontario Shield. Ontario reported 1.37 tC/ha/year for forests within "large parks"; we allocated this to dense forests within the Hudson Bay Lowlands which are not as commercially productive as those within the Ontario Shield.

Without additional reported values, we estimated that disturbed forests in the Hudson Bay Lowlands and Mixedwood Plains would provide NPP at the rate of 97.5% of the value for dense forests, with this percentage being equal to the known ratio for the Ontario Shield (1.57/1.61). Sparse forests in the Ontario Shield were assumed to provide NPP at a rate of 1.01 tC/ha/year, derived as the average of disturbed forests (1.57 tC/ha/year) and average boreal wetlands (0.45 tC/ha/year) from McLaughlin (2004). The resulting estimate is 62.7% of the value for dense forests; this same proportion was applied to the Hudson Bay lowlands and Mixedwood Plains. The resulting parameters of NPP by type of forest by ecozone were used to derive the ONT_rNPP parameter. This Relative Net Primary

Production (NPP) parameter scales the NPP of the three types of forests within each of the three ecozones to the value of dense forest in the Ontario shield (1.61), since that forest was used to derive the ONT_RY parameter (relative yield of average hectare in Ontario compared to same in Canada).

Table 15: Net Primary Production of forests, by ecozone.

	Net Primary Production tC/ha/year		
	Hudson Bay Lowlands	Mixedwood Plains	Ontario Shield
Forest: Dense	1.37	1.79	1.61
Forest: Disturbed	1.34	1.75	1.57
Forest: Sparse	0.86	1.12	1.01
ONT_rNPP: NPP relative to Forest:Dense in Ontario Shield			
Forest: Dense	0.85	1.11	1.00
Forest: Disturbed	0.83	1.08	0.98
Forest: Sparse	0.53	0.70	0.63

Biocapacity of cropland and grazing land

Cropland biocapacity is the ability of cropland to generate food consumed by humans, while grazing lands generate biological productivity that is appropriated by animals that are consumed by humans. Ontario's cropland yield was derived from data on harvests and harvested areas of Ontario crops (in metric units) in comparison to the same for Canada. Data were sourced in 2020 from Statistics Canada Tables 32-10-0359-01, 32-10-0364-01, 32-10-0365-01 so that Ontario and Canadian data could be consistently compared.

Agricultural harvests and areas were obtained for principal field crops, fruits, and vegetables. The data included tame hay and corn for silage, but these were not included in cropland yield – instead they were used to calculate yield from grazing land, since tame hay and corn for silage are fodder crops and contribute to livestock feed. This categorization was consistent with calculations within the 2021 Edition of the National Ecological Footprint and Biocapacity Accounts, which include crops for forage and silage as grazing land products.

Yields from grazing land were calculated using raw data on estimated land area harvested and annual production of tame hay and corn for silage (in metric units) for Ontario and Canada. The method employed in this report classifies grasslands as a subcategory of grazing land, and it is therefore assumed that their yields are comparable. As such, grazing land yield was applied to grasslands.

To determine the crop and grazing land yield factors for Ontario, it was necessary to first calculate total average yields for Ontario and Canada. Total average yield was calculated by dividing total production each year by total area. To account for the relative importance (in production intensity) of each individual crop type, and to improve computational accuracy, the *weighted* average yield factor for Ontario and Canada were compared.

Production and area data from Statistics Canada did not include all crop types. Therefore, the total area for all crops in Ontario was lower than the total cropland and grazing land area reported by Statistics Canada in the Canadian census data (Statistics Canada, 2016). As a result, we used a combination of SOLRIS and OLCC spatial data and Canadian census data in the calculation of the total area of cropland and grazing land. It is assumed that these datasets capture all crop types and, therefore, these sources are a more accurate reflection of total crop and grazing land area in Ontario.

The cropland and grazing land yield factor and biocapacity results in this report differ from previous Ecological Footprint reports for the Province of Ontario. The reason for this discrepancy is due to improved access to a more robust set of crop data for Ontario and Canada (Statistics Canada, 2020). This analysis includes vegetable and fruit crop data, while previous reports used principal field crop data exclusively. Additionally, using Statistics Canada data in calculating the average yields for both Canada and Ontario had the added convenience of uniform crop type categories.

Biocapacity of freshwater (fishing grounds)

This report sourced commercial freshwater fisheries landings and aquaculture production data from Fisheries and Oceans Canada (Fisheries and Oceans Canada, 2020a, 2020b). The relative yield of fishing grounds in Ontario in 2005, 2010, and 2015 were derived by comparing the landings and aquaculture production of Ontario, relative to its freshwater area, to the same for Canada.

To calculate the yield of Ontario inland waters, an estimate of total inland water area for 2015 was obtained from the geospatial analysis. This was compared to the total area of Canada's inland waters that was recorded in NFA 2021 for 2005, 2010 and 2015. Table 16 reports results revealing that Ontario's production amount to almost half of Canadian production.

Table 16: Commercial and aquaculture fish yields.

		2005	2010	2015
Ontario inland waters	Commercial fisheries (t)	13,518	11,298	12,035
	Aquaculture (t)	4,075	4,060	4,510
	Total	17,592	15,357	16,545
Canada inland waters	Commercial fisheries (t)	31,693	27,385	27,965
	Aquaculture (t)	4,857	6,844	7,062
	Total	36,673	34,229	35,027
Ontario's production share of Canada		48%	45%	47%

Biocapacity of wetlands

Wetlands are globally important for biodiversity and for managing carbon. Nevertheless, global data about their coverage and carbon sequestration are not available as a time series from 1961 to the present. For this reason, wetlands have not been identified as a specific type of biocapacity within the National Ecological Footprint and Biocapacity Accounts. But considering the significance of wetlands in Ontario, we decided it was appropriate to include wetlands as a form of biocapacity, measured as their capacity to sequester carbon.

About a decade ago, a global research agenda was proposed for improving the national Ecological Footprint accounts (Kitzes et al, 2009). Drawing from a community of active footprint practitioners and data users, wetlands were identified as an additional land type that could warrant consideration, especially when its contribution to biocapacity could be important at sub-national scales. This possibility is codified in the Ecological Footprint Standards (Global Footprint Network, 2009) as the "use of non-conventional elements" and "biomass-substitution for carbon footprint calculations", with the proviso that results are presented with and without non-conventional practices to enable comparisons with other conventional results. Therefore, we identify wetlands as providing (unconventional) carbon sequestration biocapacity, as distinct from the (conventional) carbon sequestration provided by forest lands which also provide forest products. For this reason, Figure 12 illustrates Ontario biocapacity with "wetland c-uptake" separate from "forest c-uptake" when comparing both to Ontario's Ecological Footprint; Figure 16 and Figure 17 omit wetland biocapacity when comparing Ontario to Canada and the world.

Table 17 provides an inventory of wetland carbon sequestration rates from the literature that we used to derive rates for fens, bogs, and other wetlands, in each Ecozone in which they exist. Values from the cited research were provided as ranges; we used the (central) point estimate and generated a confidence interval from the ranges, by generating wetland biocapacity using the lowest and highest ranges for all types of wetlands in all ecozones.

This confidence interval was found to be plus or minus 34%. Source values in units of gC/m2/year were ultimately converted to tC/ha/year, as reported in Table 18 which also transfers the values to wetlands in the Mixedwood Plains and Ontario shield by scaling to the relative difference in Net Primary Production of dense forests in each ecozone. Results in the column for Mixedwood Plains and the Ontario Shield were scaled from values in the Hudson Bay lowlands. For example, the value of 0.68 in the Mixedwood Plains is equal to 0.52 (in the Hudson Bay lowlands) multiplied by the ratio of 1.79/1.37 (NPP of dense forests in the Mixedwood Plains / NPP of dense forests in the Hudson Bay lowlands, as reported in Table 15). The resulting rates of sequestration were used to derive the ONT_rNPP parameter, so the biocapacity of wetlands could be specified in global hectares.

Table 17: Ranges and reference of carbon sequestration rates

Type and location	Sequestration rate (gC/m2)			Research type	Research year	Reference
	Point estimate	Lower bound	Upper bound			
Fen in HBL	52	36	68	Primary	2011-2015	Helbig et al (2019)
Bog in HBL	80	66	94	Primary	2011-2016	Helbig et al (2019)
Boreal wetlands	45	5	85	Meta	2004	McLaughlin (2004)
HBL=Hudson Bay lowlands						

Table 18: Parameters used to derive the biocapacity of wetlands, by ecozone

	Net Primary Production tC/ha/year		
	Hudson Bay Lowlands	Mixedwood Plains	Ontario Shield
Wetlands: Peat Fens	0.52	0.68	0.61
Wetlands: Peat Bogs	0.80	1.05	0.94
Wetlands: Other	0.45	0.59	0.53
ONT_rNPP: NPP relative to Forest:Dense in Ontario Shield			
Wetlands: Peat Fens	0.32	0.42	0.38
Wetlands: Peat Bogs	0.50	0.65	0.58
Wetlands: Other	0.28	0.37	0.33

A5: Abridged Ontario 2015 Consumption Land Use Matrix (CLUM)

Category of consumption	Cropland	Grazing land	Forest products	Fishing grounds	Built-up land	Forest c-uptake	Total
Total Ecological Footprint	**0.73**	**0.32**	**1.19**	**0.12**	**0.08**	**4.58**	**7.02**
Household subtotal	**0.65**	**0.29**	**0.50**	**0.11**	**0.04**	**2.98**	**4.57**
Food	**0.44**	**0.17**	**0.04**	**0.08**	**0.00**	**0.26**	**0.99**
Bread and Cereals	0.04	0.00	0.00	0.01	0.00	0.02	0.08
Meat	0.06	0.13	0.01	0.01	0.00	0.04	0.25
Fish and Seafood	0.02	0.00	0.00	0.03	0.00	0.02	0.07
Dairy	0.07	0.02	0.00	0.00	0.00	0.03	0.12
Vegetables, Fruit, nuts	0.18	0.01	0.01	0.02	0.00	0.08	0.31
Other Food	0.05	0.00	0.01	0.01	0.00	0.04	0.12
Non-alcoholic beverages	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Alcoholic beverages	0.01	0.00	0.01	0.00	0.00	0.02	0.04
Housing	**0.01**	**0.00**	**0.16**	**0.00**	**0.01**	**0.47**	**0.65**
Actual rentals for housing	0.00	0.00	0.08	0.00	0.00	0.03	0.11
Imputed rentals for housing	0.00	0.00	0.02	0.00	0.00	0.03	0.05
Water supply and miscellaneous services relating to the dwelling	0.00	0.00	0.01	0.00	0.00	0.03	0.05
Electricity, gas and other fuels	0.00	0.00	0.05	0.00	0.00	0.37	0.43
Services for household maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Personal Transportation	**0.02**	**0.01**	**0.05**	**0.00**	**0.01**	**1.26**	**1.34**
Purchase of vehicles	0.00	0.00	0.01	0.00	0.00	0.09	0.11
Operation of personal transport equipment	0.01	0.00	0.03	0.00	0.00	0.83	0.88
Transport services	0.00	0.00	0.01	0.00	0.00	0.34	0.36
Goods	**0.07**	**0.03**	**0.09**	**0.00**	**0.01**	**0.36**	**0.57**
Clothing	0.04	0.02	0.01	0.00	0.01	0.15	0.23
Footwear	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Furniture and furnishings, carpets and other floor coverings	0.00	0.00	0.02	0.00	0.00	0.01	0.04
Household appliances	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Glassware, tableware and household utensils	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Tools and equipment for house and garden	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Medical products, appliances and equipment	0.01	0.00	0.00	0.00	0.00	0.04	0.05
Telephone and telefax equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Audio-visual, photographic and information processing equipment	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Other major durables for recreation and culture	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Other recreational items and equipment, gardens and pets	0.00	0.00	0.02	0.00	0.00	0.04	0.07
Newspapers, books and stationery	0.00	0.00	0.02	0.00	0.00	0.02	0.04
Goods for household maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Tobacco	0.01	0.00	0.00	0.00	0.00	0.01	0.02
Services	**0.12**	**0.08**	**0.15**	**0.02**	**0.01**	**0.63**	**1.02**
Out-patient services	0.00	0.00	0.02	0.00	0.00	0.03	0.06
Hospital services	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Telephone and telefax services	0.01	0.01	0.02	0.00	0.00	0.07	0.11
Recreational and cultural services	0.03	0.02	0.03	0.01	0.00	0.12	0.21
Package holidays	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pre-primary and primary education	0.01	0.01	0.02	0.00	0.00	0.08	0.12
Catering services	0.04	0.03	0.02	0.01	0.00	0.07	0.16
Accommodation services	0.01	0.00	0.00	0.00	0.00	0.01	0.03
Personal care	0.00	0.00	0.00	0.00	0.00	0.06	0.08
Personal effects n. e. c.	0.00	0.00	0.00	0.00	0.00	0.03	0.04
Financial services n. e. c.	0.00	0.00	0.02	0.00	0.00	0.06	0.08
Other services n. e. c.	0.00	0.00	0.01	0.00	0.00	0.07	0.09
Government subtotal	**0.03**	**0.01**	**0.18**	**0.01**	**0.01**	**0.50**	**0.74**
Fixed capital formation subtotal	**0.05**	**0.01**	**0.51**	**0.00**	**0.02**	**1.10**	**1.71**

A6: Abridged Ontario 2010 Consumption Land Use Matrix (CLUM)

Category of consumption	Cropland	Grazing land	Forest products	Fishing grounds	Built-up land	Forest c-uptake	Total
Total Ecological Footprint	**0.88**	**0.36**	**1.17**	**0.14**	**0.07**	**5.47**	**8.10**
Household subtotal	**0.79**	**0.33**	**0.49**	**0.13**	**0.04**	**3.68**	**5.47**
Food	**0.53**	**0.20**	**0.05**	**0.10**	**0.00**	**0.31**	**1.19**
Bread and Cereals	0.05	0.00	0.00	0.01	0.00	0.03	0.10
Meat	0.08	0.15	0.01	0.01	0.00	0.05	0.30
Fish and Seafood	0.02	0.00	0.00	0.03	0.00	0.02	0.08
Dairy	0.10	0.02	0.01	0.00	0.00	0.04	0.17
Vegetables, Fruit, nuts	0.20	0.02	0.01	0.02	0.00	0.09	0.34
Other Food	0.07	0.01	0.01	0.02	0.00	0.05	0.15
Non-alcoholic beverages	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Alcoholic beverages	0.01	0.00	0.01	0.00	0.00	0.02	0.04
Housing	**0.01**	**0.00**	**0.16**	**0.00**	**0.00**	**0.66**	**0.84**
Actual rentals for housing	0.00	0.00	0.07	0.00	0.00	0.03	0.10
Imputed rentals for housing	0.00	0.00	0.02	0.00	0.00	0.03	0.06
Water supply and miscellaneous services relating to the dwelling	0.00	0.00	0.01	0.00	0.00	0.04	0.06
Electricity, gas and other fuels	0.00	0.00	0.06	0.00	0.00	0.55	0.61
Services for household maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Personal Transportation	**0.02**	**0.01**	**0.06**	**0.00**	**0.01**	**1.57**	**1.67**
Purchase of vehicles	0.00	0.00	0.01	0.00	0.00	0.09	0.11
Operation of personal transport equipment	0.01	0.01	0.04	0.00	0.00	1.08	1.14
Transport services	0.01	0.00	0.01	0.00	0.00	0.40	0.42
Goods	**0.10**	**0.04**	**0.08**	**0.00**	**0.01**	**0.43**	**0.66**
Clothing	0.06	0.03	0.01	0.00	0.01	0.19	0.30
Footwear	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Furniture and furnishings, carpets and other floor coverings	0.00	0.00	0.02	0.00	0.00	0.02	0.04
Household appliances	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Glassware, tableware and household utensils	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Tools and equipment for house and garden	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Medical products, appliances and equipment	0.01	0.00	0.00	0.00	0.00	0.04	0.06
Telephone and telefax equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Audio-visual, photographic and information processing equipment	0.00	0.00	0.00	0.00	0.00	0.04	0.05
Other major durables for recreation and culture	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Other recreational items and equipment, gardens and pets	0.00	0.00	0.01	0.00	0.00	0.03	0.05
Newspapers, books and stationery	0.00	0.00	0.01	0.00	0.00	0.01	0.03
Goods for household maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Tobacco	0.01	0.00	0.00	0.00	0.00	0.02	0.03
Services	**0.13**	**0.08**	**0.14**	**0.03**	**0.01**	**0.71**	**1.11**
Out-patient services	0.00	0.00	0.02	0.00	0.00	0.04	0.07
Hospital services	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Telephone and telefax services	0.01	0.01	0.01	0.00	0.00	0.07	0.11
Recreational and cultural services	0.05	0.03	0.04	0.01	0.00	0.18	0.32
Package holidays	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pre-primary and primary education	0.01	0.01	0.02	0.00	0.00	0.08	0.12
Catering services	0.03	0.02	0.02	0.01	0.00	0.07	0.15
Accommodation services	0.01	0.00	0.00	0.00	0.00	0.01	0.03
Personal care	0.00	0.00	0.00	0.00	0.00	0.07	0.08
Personal effects n. e. c.	0.00	0.00	0.00	0.00	0.00	0.03	0.04
Financial services n. e. c.	0.00	0.00	0.01	0.00	0.00	0.06	0.07
Other services n. e. c.	0.00	0.00	0.01	0.00	0.00	0.07	0.09
Government subtotal	**0.03**	**0.02**	**0.18**	**0.01**	**0.01**	**0.57**	**0.82**
Fixed capital formation subtotal	**0.05**	**0.02**	**0.49**	**0.00**	**0.02**	**1.23**	**1.81**

A7: Abridged Ontario 2005 Consumption Land Use Matrix (CLUM)

Category of consumption	Cropland	Grazing land	Forest products	Fishing grounds	Built-up land	Forest c-uptake	Total
Total Ecological Footprint	**2.02**	**0.50**	**1.64**	**0.29**	**0.08**	**6.07**	**10.60**
Household subtotal	**1.88**	**0.47**	**0.79**	**0.28**	**0.05**	**4.34**	**7.80**
Food	**1.42**	**0.31**	**0.11**	**0.24**	**0.01**	**0.54**	**2.62**
Bread and Cereals	0.74	0.15	0.06	0.12	0.00	0.28	1.36
Meat	0.09	0.12	0.01	0.01	0.00	0.05	0.28
Fish and Seafood	0.05	0.00	0.00	0.05	0.00	0.02	0.13
Dairy	0.11	0.01	0.01	0.00	0.00	0.03	0.16
Vegetables, Fruit, nuts	0.31	0.01	0.02	0.03	0.00	0.08	0.45
Other Food	0.10	0.00	0.01	0.02	0.00	0.04	0.18
Non-alcoholic beverages	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Alcoholic beverages	0.02	0.00	0.01	0.00	0.00	0.03	0.05
Housing	**0.01**	**0.00**	**0.25**	**0.00**	**0.00**	**0.95**	**1.22**
Actual rentals for housing	0.00	0.00	0.10	0.00	0.00	0.04	0.15
Imputed rentals for housing	0.00	0.00	0.03	0.00	0.00	0.04	0.07
Water supply and miscellaneous services relating to the dwelling	0.00	0.00	0.01	0.00	0.00	0.04	0.06
Electricity, gas and other fuels	0.00	0.00	0.10	0.00	0.00	0.82	0.92
Services for household maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Personal Transportation	**0.04**	**0.01**	**0.10**	**0.00**	**0.01**	**1.59**	**1.75**
Purchase of vehicles	0.01	0.00	0.02	0.00	0.00	0.14	0.18
Operation of personal transport equipment	0.02	0.01	0.05	0.00	0.00	1.00	1.09
Transport services	0.01	0.00	0.02	0.00	0.00	0.44	0.49
Goods	**0.18**	**0.06**	**0.14**	**0.00**	**0.01**	**0.50**	**0.90**
Clothing	0.12	0.05	0.02	0.00	0.01	0.22	0.42
Footwear	0.01	0.01	0.00	0.00	0.00	0.01	0.03
Furniture and furnishings, carpets and other floor coverings	0.01	0.00	0.04	0.00	0.00	0.02	0.07
Household appliances	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Glassware, tableware and household utensils	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Tools and equipment for house and garden	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Medical products, appliances and equipment	0.01	0.00	0.01	0.00	0.00	0.04	0.05
Telephone and telefax equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Audio-visual, photographic and information processing equipment	0.00	0.00	0.01	0.00	0.00	0.06	0.08
Other major durables for recreation and culture	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Other recreational items and equipment, gardens and pets	0.00	0.00	0.02	0.00	0.00	0.03	0.06
Newspapers, books and stationery	0.00	0.00	0.02	0.00	0.00	0.02	0.04
Goods for household maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Tobacco	0.02	0.00	0.01	0.00	0.00	0.02	0.05
Services	**0.23**	**0.08**	**0.19**	**0.03**	**0.01**	**0.76**	**1.32**
Out-patient services	0.01	0.00	0.02	0.00	0.00	0.05	0.08
Hospital services	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Telephone and telefax services	0.03	0.01	0.02	0.00	0.00	0.08	0.14
Recreational and cultural services	0.06	0.02	0.03	0.01	0.00	0.14	0.27
Package holidays	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pre-primary and primary education	0.02	0.01	0.02	0.00	0.00	0.09	0.15
Catering services	0.07	0.03	0.03	0.01	0.00	0.09	0.23
Accommodation services	0.01	0.00	0.01	0.00	0.00	0.02	0.04
Personal care	0.00	0.00	0.01	0.00	0.00	0.06	0.07
Personal effects n. e. c.	0.01	0.01	0.01	0.00	0.00	0.03	0.06
Financial services n. e. c.	0.01	0.00	0.02	0.00	0.00	0.08	0.12
Other services n. e. c.	0.00	0.00	0.02	0.00	0.00	0.09	0.12
Government subtotal	**0.06**	**0.02**	**0.22**	**0.01**	**0.01**	**0.60**	**0.91**
Fixed capital formation subtotal	**0.08**	**0.02**	**0.63**	**0.01**	**0.02**	**1.14**	**1.89**

References Cited

Borucke M, Moore D, Cranston G, Gracey K, Iha K, Larson J, Lazarus E, Morales JC, Wackernagel M, Galli A (2013). Accounting for demand and supply of the Biosphere's regenerative capacity: the National Footprint Accounts' underlying methodology and framework. *Ecological Indicators*, 24, 518-533.

Department of Economic and Social Affairs (2018). Classification of Individual Consumption According to Purpose (COICOP). New York: United Nations.

Environment and Climate Change Canada (2020). Canada's Official Greenhouse Gas Inventory. Retrieved from https://open.canada.ca/data/en/dataset/779c7bcf-4982-47eb-af1b-a33618a05e5b

Fisheries and Oceans Canada (2020a). Aquaculture production quantities and value. Retrieved from https://www.dfo-mpo.gc.ca/stats/aqua/aqua-prod-eng.htm

Fisheries and Oceans Canada (2020b). Freshwater landings. Retrieved from https://www.dfo-mpo.gc.ca/stats/commercial/fresh-yrlist-eng.htm

Global Footprint Network (2009). Ecological Footprint Standards 2009. Oakland: Global Footprint Network. Retrieved from https://www.footprintnetwork.org/content/images/uploads/Ecological_Footprint_Standards_2009.pdf

Helbig, M., Humphreys, E.R. and Todd, A. (2019). Contrasting temperature sensitivity of CO2 exchange in peatlands of the Hudson Bay Lowlands, Canada. *Journal of Geophysical Research: Biogeosciences*, 124(7), 2126-2143.

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2018). Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for the Americas of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. J. Rice, C.S. Seixas, M.E. Zaccagnini, M. Bedoya-Gaitán, N. Valderrama, C.B. Anderson, M.T.K. Arroyo, M. Bustamante, J. Cavender-Bares, A. Díaz-de-León, S. Fennessy, J. R. García Marquez, K. Garcia, E.H. Helmer, B. Herrera, B. Klatt, J.P. Ometo, V. Rodriguez Osuna, F.R. Scarano, S. Schill and J. S. Farinaci (eds.). Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) Secretariat, Bonn, Germany.

Isman, M., Archambault, M., Racette, P., Konga, C. N., Llaque, R. M., Lin, D., M.Ouellet-Plamondon, C. (2018). Ecological Footprint Assessment for Targeting Climate Change Mitigation in Cities: A case study of 15 Canadian cities according to census metropolitan areas. *Journal of Cleaner Production*, 1032-1043.

Kitzes, J., Galli, A., Bagliani, M., Barrett, J., Dige, G., Ede, S., Erb, K., Giljum, S., Haberl, H., Hails, C. and Jolia-Ferrier, L. (2009). A research agenda for improving national Ecological Footprint accounts. *Ecological Economics*, *68*(7), 1991-2007.

Lin, D., Hanscom, L., Martindill, J., Borucke, M., Cohen, L., Galli, A., Lazarus, E., Zokai, G., Iha, K., Eaton, D., Wackernagel, M., Kapoor, C. (2021). Working Guidebook to the National Footprint and Biocapacity Accounts. Oakland: Global Footprint Network.

Lin, D., Hanscom, L., Murthy, A., Galli, A., Evans, M., Neill, E., Mancini, M.S., Martindill, J., Medouar, F.-Z., Huang, S., Wackernagel, M. (2018). Ecological Footprint Accounting for Countries: Updates and Results of the National Footprint Accounts, 2012–2018. *Resources, 7,* 58.

McLaughlin, J. (2004). Carbon Assessment in Boreal Wetlands of Ontario. Forest Research Information Paper No.158. Ontario Forest Research Institute, Ontario Ministry of Natural Resources.

Ontario Biodiversity Council (2011). Ontario's Biodiversity Strategy 2011: Protecting what sustains us. A report of the Ontario Biodiversity Council, Peterborough, ON.

Ontario Biodiversity Council (2015). State of Ontario's Biodiversity 2015: Summary. A report of the Ontario Biodiversity Council, Peterborough, ON.

Ontario Ministry of Energy (2017). Ontario's energy mix at the end of 2015. From Long-Term Energy Plan: Discussion Guide. Retrieved from https://www.ontario.ca/document/2017-long-term-energy-plan-discussion-guide/ontarios-energy-mix-end-2015

Ontario Ministry of Finance (2020). Ontario's long-term report on the economy. Queen's printer for Ontario. Retrieved from https://files.ontario.ca/mof-long-term-report-book-2020-06-03-en.pdf

OMNR: Ontario Ministry of Natural Resources (2008). Southern Ontario Land Resource Information System (SOLRIS): Phase 2 - Data Specifications Version 1.2. Retrieved from https://www.sse.gov.on.ca/sites/MNR-PublicDocs/EN/CMID/SOLRIS%20Data%20Specification.pdf

OMNR: Ontario Ministry of Natural Resources (2009). Lakes and Rivers. Retrieved from https://web.archive.org/web/20140323134120/http://www.mnr.gov.on.ca/en/Business/Water/2ColumnSubPage/STEL02_163597.html

OMNR: Ontario Ministry of Natural Resources (2015). Net primary productivity. Updated April 2015. Indicator reported in State of Ontario's Natural Resources - Forest Indicators / Criterion: Maintaining forest productivity and resilience. Retrieved from https://www.ontario.ca/page/net-primary-productivity

OMNRF: Ontario Ministry of Natural Resources and Forestry (2014). Ontario Land Cover Compilation Data Specifications Version 2.0. Retrieved from https://www.sse.gov.on.ca/sites/MNR-PublicDocs/EN/CMID/Ontario%20Land%20Cover%20Compilation%20-%20Data%20Specification%20Version.pdf

OMNRF: Ontario Ministry of Natural Resources and Forestry (2016a). State of Ontario's Natural Resources - Forest 2016. Queen's Printer for Ontario. Sault Ste. Marie, ON.

OMNRF: Ontario Ministry of Natural Resources and Forestry (2016b). Forest Resources of Ontario 2016. https://www.ontario.ca/document/forest-resources-ontario-2016

OMNRF: Ontario Ministry of Natural Resources and Forestry (2019). Southern Ontario Land Resource Information System (SOLRIS) Version 3.0. Data Specifications. Retrieved from https://www.sse.gov.on.ca/sites/MNR-PublicDocs/EN/CMID/SOLRIS%20v3.0%20-%20Data%20Specifications.pdf

Statistics Canada (2015). Corn: Canada's third most valuable crop. Retrieved from https://www150.statcan.gc.ca/n1/pub/96-325-x/2014001/article/11913-eng.htm.

Statistics Canada (2016). Chapter 7 Price and volume measures. In Canadian System of Macroeconomic Accounts (pp. 4-39). Ottawa: Ministry of Industry.

Statistics Canada (2016). Land Use. Retrieved from https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210040601

Statistics Canada (2017). A portrait of a 21st century agricultural operation. Retrieved from https://www150.statcan.gc.ca/n1/pub/95-640-x/2016001/article/14811-eng.htm

Statistics Canada (2017). User Guide for the Survey of Household Spending, 2015. Ottawa: Minister of Industry.

Statistics Canada (2020). Table 11-10-0222-01 Household spending, Canada, regions and provinces. Retrieved from https://doi.org/10.25318/1110022201-eng

Statistics Canada (2020). Table 17-10-0005-01 Population estimates on July 1st, by age and sex. Retrieved from https://doi.org/10.25318/1710000501-eng

Statistics Canada (2020). Table 18-10-0005-01 Consumer Price Index, annual average, not seasonally adjusted. Retrieved from https://doi.org/10.25318/1810000501-eng

Statistics Canada (2020). Table 18-10-0007-01 Basket weights of the Consumer Price Index, Canada, provinces, Whitehorse, Yellowknife and Iqaluit. Retrieved from https://doi.org/10.25318/1810000701-eng

Statistics Canada (2020). Table 25-10-0001-01 Electric power statistics, with data for years 1950 - 2007. Retrieved from https://doi.org/10.25318/2510000101-eng

Statistics Canada (2020). Table 25-10-0015-01 Electric power generation, monthly generation by type of electricity. Retrieved from https://doi.org/10.25318/2510001501-eng

Statistics Canada (2020). Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units. Retrieved from https://doi.org/10.25318/3210035901

Statistics Canada (2020). Table 32-10-0364-01 Area, production and farm gate value of marketed fruits. Retrieved from https://doi.org/10.25318/3210036401

Statistics Canada (2020). Table 32-10-0365-01 Area, production and farm gate value of marketed vegetables. Retrieved from https://doi.org/10.25318/3210036501

Statistics Canada (2020). Table 36-10-0222-01 Gross domestic product, expenditure-based, provincial and territorial, annual. Retrieved from https://doi.org/10.25318/3610022201

Statistics Canada (2020). Table 38-10-0097-01 Physical flow account for greenhouse gas emissions. Retrieved from https://doi.org/10.25318/3810009701

Stechbart, M., and J. Wilson (2010). Province of Ontario Ecological Footprint and Biocapacity analysis. Produced for State of Ontario's Biodiversity 2010 Report. Published by the Global Footprint Network.

Western Sarnia-Lambton Research Park (2013). Assessment of Hay Crop Acreage and Pasture Land for Biomass Production in Ontario. Prepared for Ontario Federation of Agriculture.

York University and Global Footprint Network (2020). National Ecological Footprint and Biocapacity Accounts, 2021 Edition. Produced for the Footprint Data Foundation. Distributed by Global Footprint Network. Available at https://data.footprintnetwork.org

Zokai,G., Ortego, J., Zimmerman, D., Wackernagel, M. (2015). The footprint and biocapacity of Ontario, Canada: Comparing results for 2005 and 2010. Oakland, CA. Global Footprint Network.