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Ecosystem Accounting for Large Urban Areas in Canada

by Stéphanie Uhde, Pier-Olivier Tremblay, Jonathan Whiteley
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Acronyms

AAFC: Agriculture and Agri-Food Canada

CA: Census agglomeration

CAAQS: Canadian Ambient Air Quality Standards

CanCHEC: Canadian Census Health and Environment Cohort

CMA: Census metropolitan area

CO: Carbon monoxide

CoE: Census of Environment

CSA: Contiguously settled area

CT: Census tract

DA: Dissemination area

ECCC: Environment and Climate Change Canada

FAPAR: Fraction of absorbed photosynthetically active radiation

FVC: Fraction of vegetation cover

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC: Intergovernmental Panel on Climate Change

IUCN: International Union for Conservation of Nature

IUCN GET: International Union for Conservation of Nature Global Ecosystem Typology

KMGBF: Kunming-Montreal Global Biodiversity Framework

LAI: Leaf area index

LiDAR: Light detection and ranging

MODIS: Moderate Resolution Imaging Spectroradiometer

NDVI: Normalized Difference Vegetation Index

NHN: National Hydrographic Network

NO_2: Nitrogen dioxide

NPRI: National Pollutant Release Inventory

NRCan: Natural Resources Canada

O_3: Ozone

OECD: Organisation for Economic Co-operation and Development

$PM_{2.5}$: Particulate matter that is 2.5 microns in diameter and less (fine particulate matter)

POPCTR: Population centre

SDG: Sustainable Development Goal

SEEA EA: System of Environmental-Economic Accounting – Ecosystem Accounting

SO_2: Sulphur dioxide

UN: United Nations

USDA: United States Department of Agriculture

VOC: Volatile organic compound

1 Introduction

Urban areas represent intensively used land and highly modified ecosystems. They are characterized by high-density human settlements and are heavily influenced by human intervention (Keith et al., 2020).

In Canada, like in many areas of the world, most people live in urban areas (Ritchie et al., 2024; Statistics Canada, 2022a). People who live or work in urban areas face various environmental challenges related to biodiversity loss, climate change and environmental quality, as well as environmental inequality, which is a cross-cutting issue. These challenges have a significant impact on health and other aspects of well-being and represent key policy concerns for local governments (for example, C40, 2025; Ville de Montréal, n.d.; International Union for Conservation of Nature, 2023; Lulham et al., 2023; World Council on City Data, n.d.).

Although urban areas are largely covered by grey spaces such as buildings, roads and parking lots, they also contain green and blue spaces such as parks, street trees, rivers, ponds and gardens. These green and blue assets, including engineered elements such as green roofs, supply ecosystem services, which contribute to benefits experienced by people who live or work in urban areas. These benefits include reduced impacts of environmental hazards, enhanced adaptation to environmental conditions, and improved physical and mental health through recreation.

The objective of this framework is to provide the conceptual foundation for the development of ecosystem accounts for large urban areas in Canada, based on the United Nations (UN) System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA) (United Nations et al., 2021). It presents the scope of the ecosystem accounts for large urban areas and describes underlying concepts, important urban-specific environmental issues and relevant ecosystem services (Textbox 1).

The focus is on ecosystem changes that have direct impacts on the well-being of local residents and workers. However, activities in large urban areas can also impact the environment and people living elsewhere. For example, the demand from people in urban areas for industrial and agricultural goods can cause pollution emissions in other regions and countries (Elmqvist et al., 2013; Haberman and Bennett, 2019).

The ecosystem accounts for large urban areas will provide a structure for integrating data on urban ecosystem extent and condition, the ecosystem services generated by these areas, and the benefits for local communities. Data and information provided can be used to address a broad set of issues linking the environment and urban populations, such as how changes in ecosystem condition in and near cities affect well-being.

Accounts data can be used to help assess the benefits associated with investments in urban green and blue assets, especially in the context of climate change. For example, the accounts will provide estimates of water flow regulation (flood mitigation) services supplied by green spaces.

Data from the accounts can also support the compilation of policy-relevant indicators, including UN Sustainable Development Goals (SDGs) and the Kunming-Montreal Global Biodiversity Framework (KMGBF). Some examples are the average share of the built-up area of cities that is green/blue space for public use for all (headline indicator 12.1 of the KMGBF); the average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities (UN SDG indicator 11.7.1); and services provided by ecosystems (indicator B.1 of the KMGBF).

These accounts are being developed as part of Statistics Canada's Census of Environment (CoE) program. The CoE reports on ecosystems in Canada, providing information to help Canadians make evidence-based decisions to protect and enhance the environment.

Framework organization and guidelines

The ecosystem accounting framework for large urban areas in Canada follows the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA). Ecosystem accounts organize information on different types of ecosystems, tracking changes in extent and condition and estimating ecosystem services, according to an international statistical standard (Statistics Canada, 2023a).

Other guidelines exist that deal with accounting for natural assets in urban settings, such as the guide for natural asset disclosures by local governments from the Intact Centre on Climate Adaptation and the University of Waterloo (Eyquem, 2024). These initiatives support natural asset reporting by local governments and help make local data more comparable. This ecosystem accounting framework, however, will apply national accounting principles and concepts.

The framework is organized according to the SEEA EA core accounts as follows:

Section 2, “Defining ecosystem accounts for large urban areas in Canada,” provides information on key concepts and the scope of these accounts.

Section 3, “Ecosystem extent,” identifies and presents data on the size and growth of large urban areas.

Section 4, “Ecosystem condition and urban-specific environmental issues,” explains important environmental issues affecting the well-being of people who live and work in large urban areas and presents condition characteristics and proposed metrics for urban ecosystems.

Section 5, “Ecosystem services,” describes seven selected ecosystem services used by urban beneficiaries, as well as the proposed metrics for pilot ecosystem accounts.

Section 6, “Environmental inequality,” raises additional considerations in the context of ecosystem accounting for large urban areas and provides examples of environmental inequality metrics.

The thematic focus of this framework is large urban areas, in recognition of the specific environmental impacts present in these areas. For example, the predominance of impervious surfaces intensifies heat waves because of the urban heat island effect and increases surface runoff, which can lead to sewer overflows. Densification can lead to a reduction in green spaces and an increase in traffic, contributing to higher concentrations of air pollutants (Deilami et al., 2018; Haaland & Konijnendijk van den Bosch, 2015; Health Canada, 2022a; Intergovernmental Panel on Climate Change [IPCC], 2023a).

The choice of condition characteristics was guided by logic chains that focus on population well-being. Well-being encompasses prosperity and other factors such as health, environmental quality and safety (Organisation for Economic Co-operation and Development [OECD], 2020). An approach that focuses on well-being and health encompasses some of the key environmental policy concerns associated with large urban areas, such as extreme heat issues.

This framework sets the foundation for developing the ecosystem accounts for large urban areas in Canada. Its implementation will rely on the continued identification and integration of appropriate data and methods. Metrics are proposed based on both relevance and potential feasibility. While data are available or currently being developed for some metrics, other proposed metrics are more aspirational and will require additional research and development. These different stages of progress are reflected in the level of detail in the data and methods presented here. Ongoing research, partnerships and engagement with experts and the public will be used to enrich and refine the accounts over time.

2 Defining ecosystem accounts for large urban areas in Canada

Urban areas can be defined in different ways. For example, urban areas delineated based on administrative boundaries differ from urban areas defined by population size and density or by economic activity (Textbox 2). From an ecosystem perspective, urban areas form a distinct type of ecosystem, with an observable morphological footprint.

This ecosystem accounting framework and the associated data target large urban areas, although some of the concepts related to urban ecosystem condition and services will be relevant to smaller areas as well. In Canada, the largest urban areas are concentrated along the southern border. While large urban areas make up only 0.1% of Canada's landscape,[1] the many people who live and work there experience specific environmental challenges and vulnerabilities.

2.1 What are urban ecosystems?

In the SEEA EA, ecosystems are seen as a contiguous space characterized by a specific and "distinct set of biotic and abiotic components and their interactions" (United Nations et al., 2021, para. 2.11). The SEEA EA uses the International Union for Conservation of Nature Global Ecosystem Typology (IUCN GET) as the reference ecosystem classification for ecosystem accounting.

Urban and industrial ecosystems, including cities, smaller settled areas and industrial areas, are an ecosystem functional group under the intensive land-use biome of the IUCN GET. They are described as structurally complex areas characterized by a patchwork of buildings, roads and other artificial surfaces, but also of bare ground and vegetation or water features of different sizes and shapes (such as parks, gardens, street trees, rivers and riparian areas). Urban and industrial ecosystems often have simplified biotic communities and altered ecosystem functions and are highly dependent on external flows of water, energy and nutrients (Keith et al., 2020).

Land cover classes based on Earth observation data can help identify artificial surfaces and built-up areas, including settled areas, roads, industrial areas, mines and quarries, farmsteads, and small or isolated settlements.

Using Earth observation derived land cover data, Statistics Canada has created geographies known as contiguously settled areas (CSAs) to represent settled areas based on their morphological footprint (for more information, see Allen & Henry, 2023). CSA boundaries correspond to the biophysical transition between the urban ecosystem and adjacent natural, semi-natural and agricultural ecosystems, aligning with the IUCN GET "urban and industrial ecosystems" class.

CSAs were delineated for population centres (POPCTRs) with over 5,000 people, based on the 2021 Census of Population. CSAs associated with large urban POPCTRs, which have a population size of 100,000 or more, are the large urban areas targeted by this framework.[2]

1. This percentage is the proportion of the total area of the country that is occupied by large contiguously settled areas, corresponding to large urban population centres.
2. This definition relies on the size of the population within the perimeter of the POPCTR, which may differ from the size of the population within the perimeter of the CSA.

Urban geographic areas and the need for morphological boundaries for ecosystem accounting

There are many different geographic representations of urban areas. Census geographies, such as population centres (POPCTRs), do not fully represent the distinct biophysical characteristics associated with urban ecosystems. They overbound or underbound the morphological footprint of urban ecosystems by including large areas of natural, semi-natural or agricultural land on the periphery of the settled area, or by excluding portions of contiguous settled areas (Map 1).

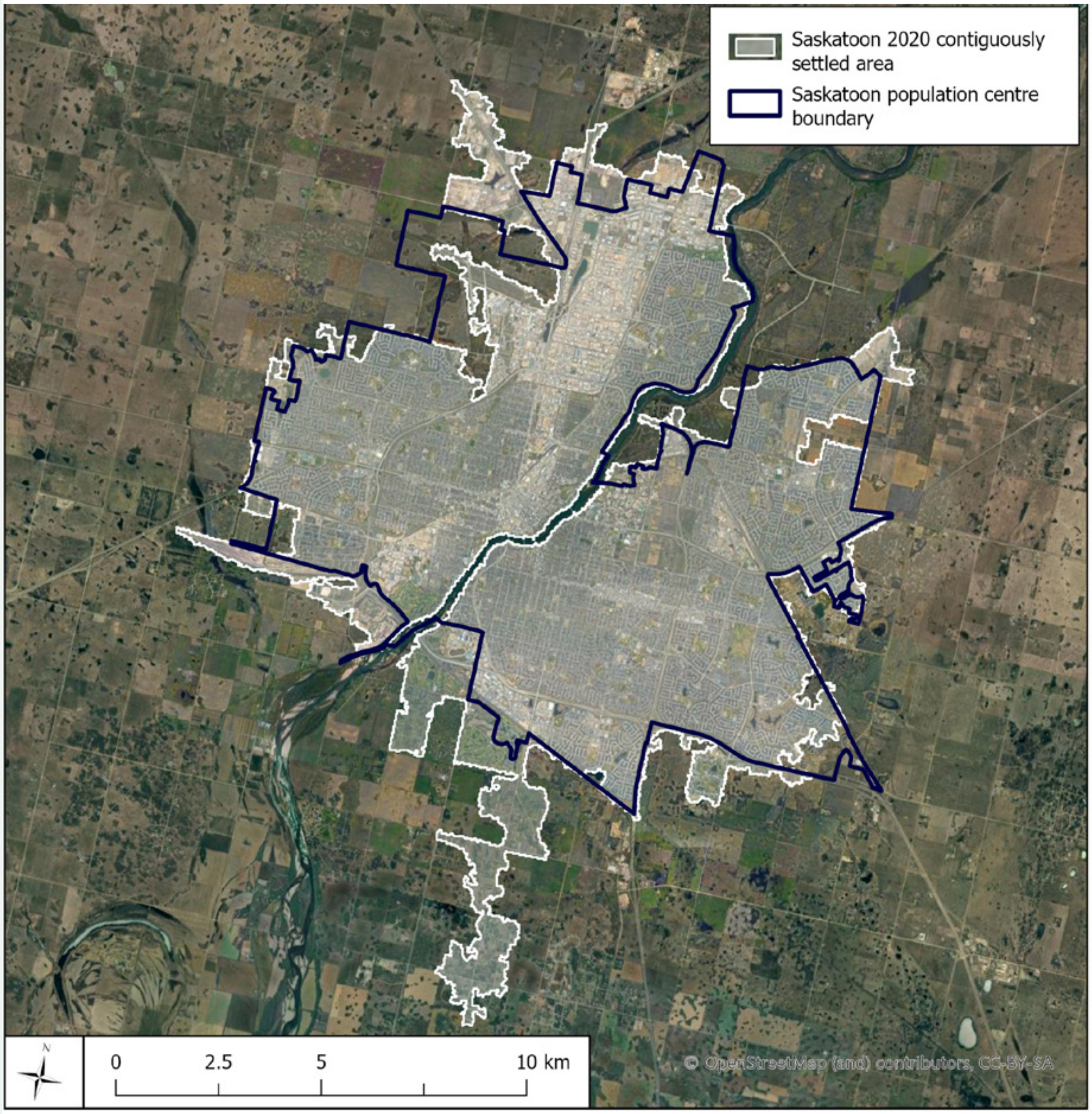
POPCTRs are areas with a population of at least 1,000 and a population density of 400 or more people per square kilometre. Large urban POPCTRs have a population of 100,000 or more, medium POPCTRs have a population from 30,000 to 99,999 and small POPCTRs have a population under 30,000 people. All areas outside POPCTRs are considered rural (Statistics Canada, 2023b).

Census metropolitan areas (CMAs) and census agglomerations (CAs) are formed by one or more adjacent municipalities centred on a POPCTR (known as the core). CMAs and CAs can include one or more POPCTRs, as well as rural areas between them. To be included within the CMA or CA, adjacent municipalities must have a high degree of economic integration with the core, measured using commuting flows. CMAs have a total population of at least 100,000, of which 50,000 must live within the core (Statistics Canada, 2023b).

Contiguously settled areas (CSAs) represent settled areas according to the morphological footprint of the urban ecosystem on the landscape (Allen and Henry, 2023).[3] CSA boundaries were delineated for POPCTRs with over 5,000 people and for smaller POPCTRs that fall within a CMA or CA, based on 2021 Census of Population data. The CSAs are derived from Agriculture and Agri-Food Canada's (AAFC's) Semi-decadal Land Use Time Series (AAFC, 2023a), which have a 30 metre resolution and are mostly based on Earth observation.

3. Other countries have also developed areas similar to Canada's CSAs, such as the European Environment Agency's Urban Morphological Zones; accessed October 17, 2024) and the Open Built Up Areas of Great Britain by Ordnance Survey; accessed October 17, 2024).

Map 1
Contiguously settled area of Saskatoon, 2020, with 2021 population centre boundary



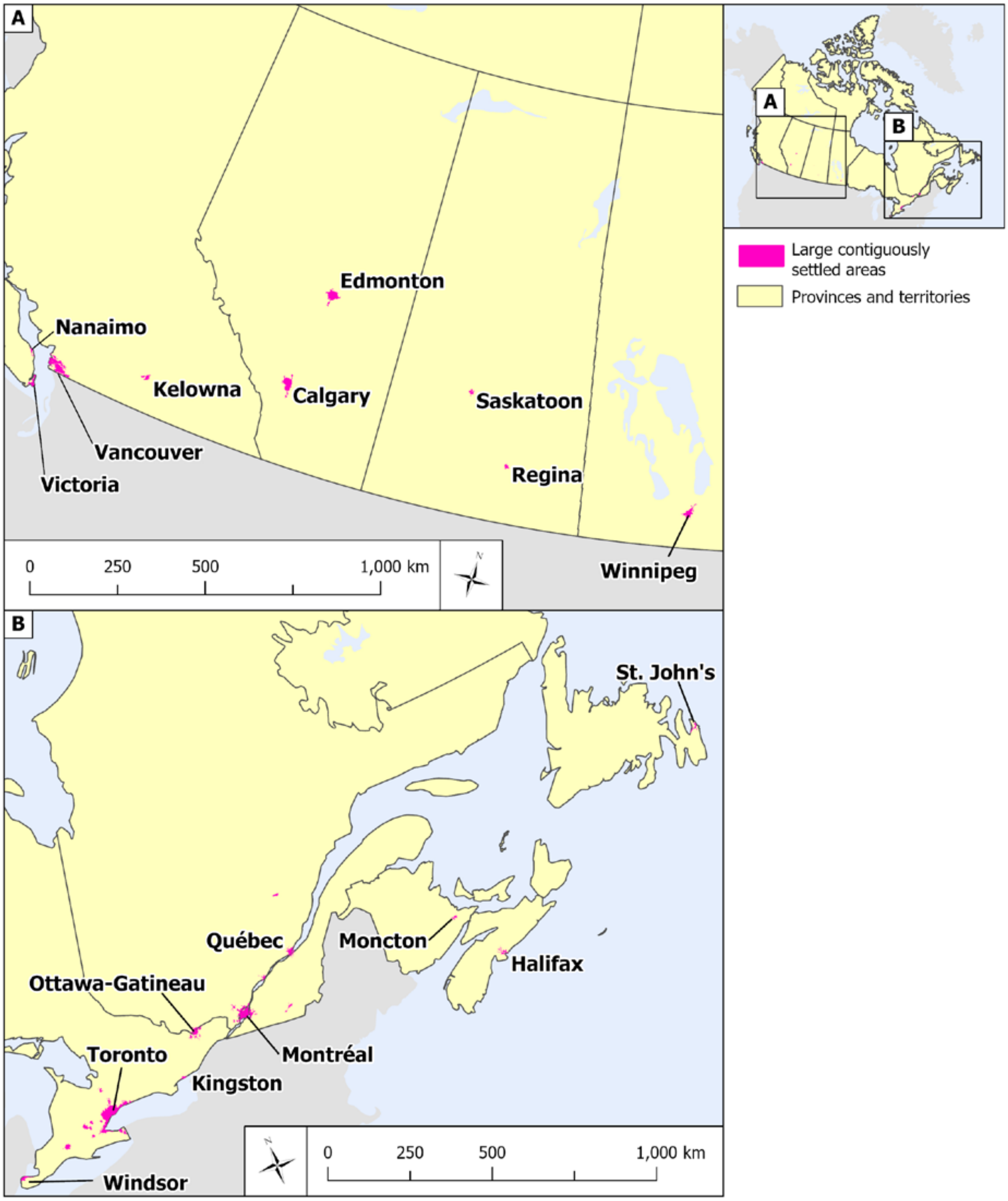
Sources: Statistics Canada. (2023c). Contiguously Settled Areas: Settlement footprints, 2010 and 2020 [Data set]. Retrieved February 25, 2025. https://open.canada.ca/data/en/dataset/99464b99-92ef-462f-b67a-85cea6b986fc; Statistics Canada. (2023d). 2021 Census Boundary files [Data set]. Retrieved February 25, 2025. https://www12.statcan.gc.ca/census-recensement/2021/geo/sip-pis/boundary-limites/index2021-eng.cfm?year=21.

2.2 Core and extended accounting areas

This framework proposes two levels of geographic areas relevant to ecosystem accounting for large urban areas in Canada.

The main set of tables will apply to a core accounting area made up of the 30 large CSAs (Section 2.1 and Map 2). Ecosystem accounts for large urban areas in Canada will be compiled for the core accounting area, including estimates of ecosystem extent, condition and services. Depending on data availability, the scope of the urban ecosystem accounts for Canada could eventually be expanded to smaller CSAs, although environmental challenges may be different for smaller centres (Kendal et al., 2020).

Map 2
Large contiguously settled areas in Canada, 2020



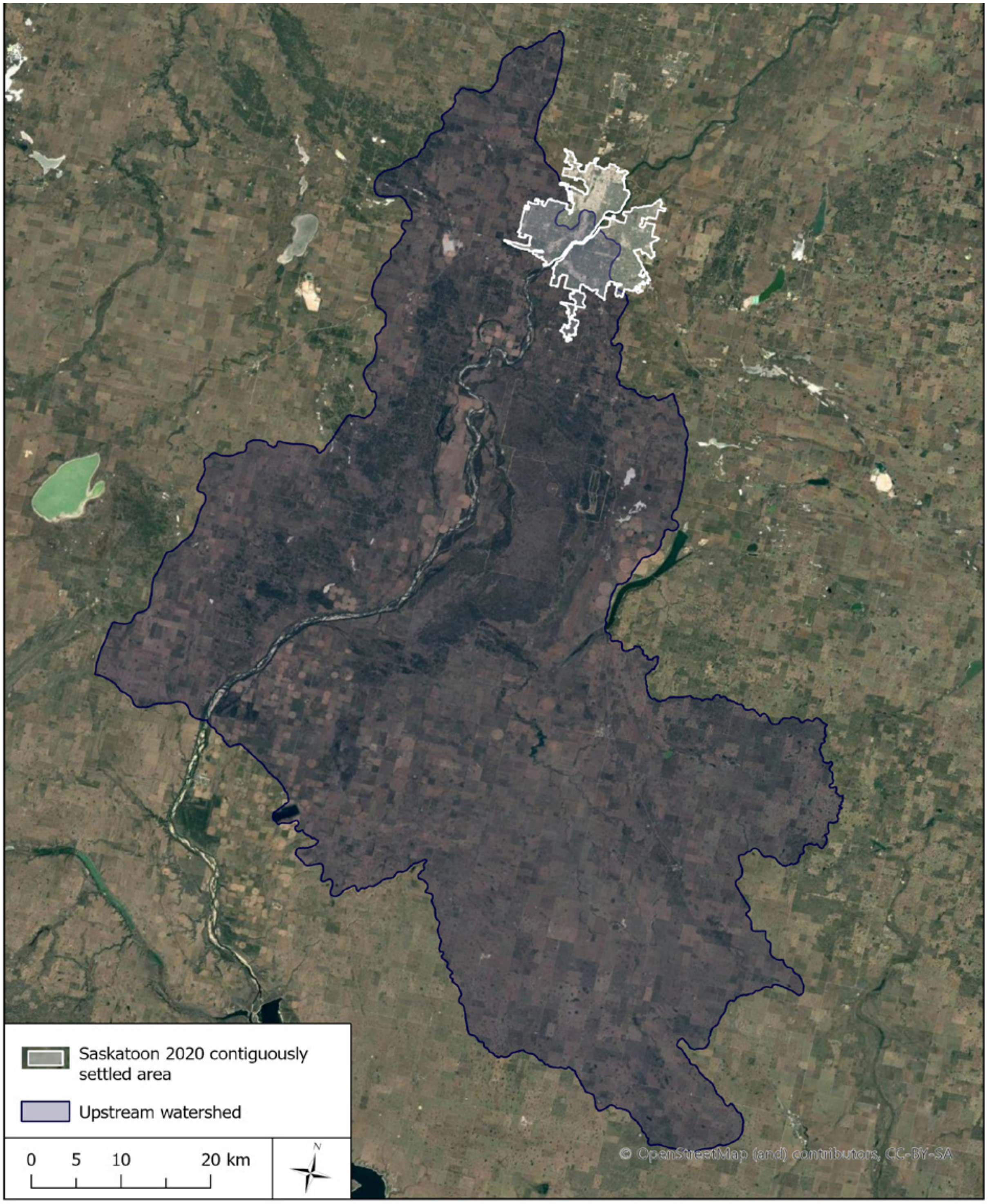
Sources: Statistics Canada. (2023c). Contiguously Settled Areas: Settlement footprints, 2010 and 2020 [Data set]. Retrieved February 25. 2025. https://open.canada.ca/data/en/dataset/99464b99-92ef-462f-b67a-85cea6b986fc; Statistics Canada, Environment Accounts and Statistics Division.

One limitation of defining the core accounting area based on CSA boundaries is that ecosystems outside the urban boundaries that supply services to the urban population are excluded from the account tables. An extended accounting area is proposed, to consider the flow of some important ecosystem services from nearby ecosystems into urban areas.

The extended accounting area corresponds to the watersheds immediately upstream of large urban areas, which directly influence water supply services and water flow regulation services to mitigate extreme water-related events for the urban population (Map 3 and Section 5.2). The proximity of these watersheds to the urban area also means that pressures from urbanization may be stronger there than further upstream.

However, the extended accounting area does not cover the entirety of the “serviceshed” where ecosystem services are supplied and used (Zhang et al., 2025). For water supply services and water flow regulation services to mitigate extreme water-related events, the serviceshed may be much larger than the immediate upstream watersheds and could include terrestrial and freshwater ecosystems anywhere in the major upstream drainage area. Similarly, municipalities may draw water from downstream drainage areas. The definition of the extended accounting area based on the immediate upstream watersheds is seen as a first step in accounting for ecosystem services that originate from outside urban areas, potentially including recreation and education services.

Map 3
Watershed upstream of contiguously settled area of Saskatoon, 2020



Sources: Natural Resources Canada. (2022). National Hydro Network - NHN - GeoBase Series [Data set]. Retrieved February 25, 2025. https://open.canada.ca/data/en/dataset/a4b190fe-e090-4e6d-881e-b87956c07977; Statistics Canada. (2023c). Contiguously Settled Areas: Settlement footprints, 2010 and 2020 [Data set]. Retrieved February 25. 2025. https://open.canada.ca/data/en/dataset/99464b99-92ef-462f-b67a-85cea6b986fc.

3 Ecosystem extent

Ecosystem extent for large urban areas is equivalent to the area of CSAs making up the core accounting area. Urban ecosystem extent evolves through urban expansion, also known as urban sprawl.

In 2020, large urban areas covered more than 11,000 square kilometres of Canada's inland area, up 2.4% from 2010 (Table 1). The CSAs of Toronto, Calgary and Edmonton grew the most over this period, while the rate of change was highest in Milton.

Tracking the evolving footprint of urban ecosystems provides estimates of the addition of new settled areas to urban areas. Other ecosystem types that surround urban ecosystems—including forests, croplands, wetlands, and lakes and rivers—are lost or degraded through urban expansion.

Table 1
Ecosystem extent for large urban areas

Contiguously settled areas	2010	2020	Percentage change from 2010 to 2020
	km²		percent
Total, large contiguously settled areas	11,057.97	11,322.81	2.4
Toronto, Ontario	2,352.19	2,405.61	2.3
Vancouver, British Columbia	1,323.74	1,344.38	1.6
Montréal, Quebec	1,291.91	1,311.52	1.5
Calgary, Alberta	851.90	885.04	3.9
Edmonton, Alberta	796.43	820.52	3.0
Winnipeg, Manitoba	535.64	555.37	3.7
Ottawa–Gatineau (Ontario portion), Ontario	437.02	452.02	3.4
Québec, Quebec	370.89	374.98	1.1
Kitchener, Ontario	251.33	257.28	2.4
Halifax, Nova Scotia	251.65	253.05	0.6
Victoria, British Columbia	241.31	243.37	0.9
London, Ontario	216.42	227.62	5.2
Kelowna, British Columbia	206.72	211.16	2.2
Windsor, Ontario	191.09	193.41	1.2
St. Catharines–Niagara Falls, Ontario	170.15	174.72	2.7
St. John's, Newfoundland and Labrador	160.58	162.51	1.2
Ottawa–Gatineau (Quebec portion), Quebec	153.61	155.66	1.3
Saskatoon, Saskatchewan	145.95	153.93	5.5
Regina, Saskatchewan	126.88	132.09	4.1
Sherbrooke, Quebec	128.50	130.50	1.6
Moncton, New Brunswick	115.76	117.12	1.2
Trois-Rivières, Quebec	99.62	103.33	3.7
Chicoutimi–Jonquière, Quebec	98.47	100.09	1.6
Saint-Jérôme, Quebec	95.74	97.02	1.3
Nanaimo, British Columbia	96.09	96.54	0.5
Kingston, Ontario	89.80	91.62	2.0
Barrie, Ontario	84.19	88.47	5.1
Guelph, Ontario	74.27	77.14	3.9
Brantford, Ontario	61.12	62.73	2.6
Milton, Ontario	39.00	44.00	12.8

Notes: The values provided in this table have been rounded. Increases in the area of a contiguously settled area (CSA) over time do not necessarily imply a conversion of natural, semi-natural or agricultural land to built-up land for the entire area of change. For instance, the increases may also be due to non-built-up land becoming enclosed in the CSA by built-up area growth. For more details, see Allen and Henry (2023) and Statistics Canada (2023c). The Ottawa-Gatineau (Ontario portion) and Ottawa-Gatineau (Quebec portion) CSA geographies are associated with a population centre that crosses a provincial boundary and has been split into its provincial portions. To calculate the extent for the entire CSA, users can sum the extent of the two portions.
Source: Statistics Canada. (n.d.-a), Table 38-10-0163-01 Extent and growth of contiguously settled areas [Data table]. Retrieved March 20, 2025. https://doi.org/10.25318/3810016301-eng.

Urban ecosystems can be further classified by their component areas, such as by detailed land cover or land use class. One example of classifying component areas within urban ecosystems is by identifying green and blue spaces, versus grey spaces, which are areas mainly covered with impervious surfaces such as buildings, roads and parking lots.

Urban green and blue spaces (Textbox 3) provide important contributions to the well-being of the people who live and work in urban areas by supplying ecosystem services. For example, they filter air pollutants, cool down air temperature and reduce flood risks. Development or densification within the existing urban boundaries can result in the loss or degradation of these spaces (Haaland & Konijnendijk van den Bosch, 2015; Mohajeri et al., 2015).

Measuring urban green and blue spaces is a focus of international indicators, such as KMGBF indicator 12.1[4] and UN SDG indicator 11.7.1[5] Progress toward measuring these indicators for cities across the country will require mapping urban green and blue spaces for public use in a consistent, comprehensive way. The presence of vegetation and water in cities is treated as a condition of the urban ecosystem and is described further in Section 4.

Urban green and blue spaces and related concepts

Urban green and blue spaces refer to the presence of vegetation and water in urban areas. The KMGBF defines green and blue spaces as “areas of vegetation, inland and coastal waters, generally in or near to urban areas and other densely populated areas” (Convention on Biological Diversity, n.d., “Explanation of the target and its elements”).

Common examples of urban green spaces include public and private parks, yards, street trees, grassy areas (e.g., cemeteries), and engineered elements designed to mimic the functions of nature (e.g., green roofs, bioswales, rain gardens and other landscaped stormwater management features). Additionally, underused areas, such as vacant lots and vegetated edges alongside roads, railways and rivers, can provide comparable ecosystem services (Luo & Patuano, 2023; Mendes et al., 2024; Sikorski et al., 2021).

Accurately identifying urban green spaces using Earth observation imagery poses significant challenges. Green spaces are often small and incorporate some built features. Public parks, for example, frequently include paved surfaces, playgrounds and small buildings. Depending on the resolution of the data source, these unvegetated areas may affect the measurement of green spaces (Section 4.6).

Similarly, some types of urban blue spaces are more easily identified than others. Lakes, rivers and coastlines are the largest and most noticeable water features in cities. However, smaller water bodies such as ponds also supply ecosystem services in urban areas (Ribbe et al., 2024).

Green infrastructure refers to the management and interconnection of green and blue spaces to support ecosystem services that benefit urban populations (IPCC, 2023b). Nature-based solutions are a broader concept referring to actions that leverage natural processes to address sustainable development issues (Cohen-Shacham et al., 2016; for more information about these concepts, see Canadian Council of Ministers of the Environment, 2021).

4 Ecosystem condition and urban-specific environmental issues

Although the link between the size of cities and the severity of the various environmental issues they face is not always straightforward, the number of people who are affected by urban environmental conditions is on the rise. In 2021, 61% of people lived in large urban POPCTRs in Canada (Statistics Canada, 2022a). From 2016 to 2021, the population grew at a faster pace in these areas (+5.8%) than in Canada overall (+5.2%), with growth rates in 26 of the 34 large urban POPCTRs ranging from 5.3% to 22.3% (Statistics Canada, 2022b).

Climate change can exacerbate environmental hazards and affect environmental quality in large urban areas. For example, rising temperatures and changes in the frequency or severity of storms, floods and wildfires affect the well-being of Canadians, including the people who live and work in large urban areas (IPCC, 2023a). In this context, maintaining the well-being of the urban population is linked to climate change adaptation measures, such as transforming impervious surfaces to permeable ones and improving access to urban green and blue spaces.

4. Average share of the built-up area of cities that is green/blue space for public use for all.
5. Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities.

Ecosystem condition accounts measure the quality of ecosystems in terms of their abiotic and biotic characteristics. They provide information on ecosystem degradation, as well as on factors that affect the supply of ecosystem services. Table 2 presents the condition characteristics and metrics proposed for this framework, based on the SEEA EA condition typology.

The condition metrics are relevant to inform urban policy or analysis, are sensitive to human pressures and responses, and show directional change over time (United Nations et al., 2021, Appendix A5.1).[6] Additionally, the condition characteristics and metrics have a strong influence on the seven selected ecosystem services identified in this framework (Section 5). Data from these metrics may be used to model the supply of ecosystem services or provide context for analysis and interpretation.

While the feasibility of compilation was considered when including condition metrics, further research and development will be necessary to develop ecosystem condition data in a comparable way across Canada for the core and extended accounting areas. Data may be incomplete or of insufficient quality, and proxies may be used. While most condition metrics should be produced by urban area, disaggregation by smaller geographies is a priority where data are available.

6. Condition characteristics that are stable or insensitive to human activity, such as precipitation, as well as information on demographics, emissions or management practices, are considered ancillary variables. These are not tracked in the condition accounts and are excluded from Table 2. Ancillary data, however, may still be relevant for the compilation of ecosystem accounts.

Table 2
Ecosystem condition characteristics and proposed metrics according to ecosystem condition typology, with link to selected ecosystem services

Group	Class	Condition characteristics	Proposed metrics	Accounting area	Link to selected services (see Section 5)
Abiotic ecosystem characteristics	Physical state	Impervious surfaces (Section 4.1)	• Proportion of impervious surfaces in total urban area	Core	• Local climate regulation • Water supply • Water flow regulation to mitigate extreme water-related events
		Surface water (Section 4.2)	• Proportion of surface water in total urban area, by type of water body • Length of shoreline bordering the urban area, by type of water body	Core	• Local climate regulation • Recreation and education • Visual amenity
		Temperature (Section 4.3)	• July and August average daily maximum (daytime) and minimum (nighttime) air temperature	Core	• Local climate regulation • Local biomass provisioning
				Extended	• Water supply • Water flow regulation to mitigate extreme water-related events
			• Three- to five-year average land surface temperature for the peak temperature period, by census tract (CT) or dissemination area (DA)	Core	• Local climate regulation • Local biomass provisioning
			• Three- to five-year average difference in daytime and nighttime land surface temperature between the urban area and its surroundings for the peak temperature period • Three- to five-year average difference in daytime land surface temperature between a CT or DA and the whole urban area for the peak temperature period • Extreme heat events (e.g., number of days when the temperature exceeds a threshold)	Core	• Local climate regulation
	Chemical state	Ambient air quality (Section 4.4)	• Annual average concentration of fine particulate matter ($PM_{2.5}$) and other pollutants such as nitrogen dioxide and ozone in outside air • Number of days per year with a concentration of $PM_{2.5}$ and other pollutants in outside air exceeding daily standards	Core	• Air filtration • Recreation and education
		Water quality (Section 4.5)	• Concentration of E. coli in water bodies	Core	• Recreation and education • Visual amenity
			• Water quality parameters (dissolved oxygen, phosphorus and nitrogen) • Proxy: Ratio of pollutants emitted by upstream facilities over the distance of facilities to the urban area • Proxy: Risk of water contamination (risk class)	Extended	• Recreation and education • Water supply

Table 2
Ecosystem condition characteristics and proposed metrics according to ecosystem condition typology, with link to selected ecosystem services

Group	Class	Condition characteristics	Proposed metrics	Accounting area	Link to selected services (see Section 5)
Biotic ecosystem characteristics	Compositional state	Vegetation type (Section 4.6.1)	• Vegetated areas, by vegetation type (cropland, treed areas and any other vegetation types)	Core	• Air filtration • Local climate regulation • Recreation and education • Visual amenity
				Extended	• Water supply • Water flow regulation to mitigate extreme water-related events
		Bird biodiversity (Section 4.7.1)	• Bird richness, diversity or presence of keystone species	Core	• Recreation and education • Visual amenity
	Structural state	Vegetation and tree canopy cover (Section 4.6.2)	• Vegetation cover, by CT or DA • Proportion of tree canopy cover in total urban area	Core	• Air filtration • Local climate regulation • Recreation and education • Visual amenity
				Extended	• Water supply • Water flow regulation to mitigate extreme water-related events
		Vegetation density (Section 4.6.3)	• Leaf area index	Core	• Air filtration • Local climate regulation
				Extended	• Water supply • Water flow regulation to mitigate extreme water-related events
	Functional state	Vegetation health (Section 4.6.4)	• Fraction of absorbed photosynthetically active radiation	Core	• Air filtration • Local climate regulation • Recreation and education • Visual amenity
				Extended	• Water supply • Water flow regulation to mitigate extreme water-related events
		Pollinator abundance (Section 4.7.2)	• Pollinator abundance (including native species)	Core	• Local biomass provisioning
Landscape-level characteristics	Landscape and seascape	Configuration of vegetated areas (Section 4.6.5)	• Average size of vegetated areas • Metrics of vegetated area shape or connectivity to be determined	Core	• Air filtration • Local climate regulation
				Extended	• Water supply • Water flow regulation to mitigate extreme water-related events

Source: Statistics Canada, Environment Accounts and Statistics Division.

4.1 Impervious surfaces

Urban ecosystems have a high proportion of impervious surfaces, which are mostly artificial features such as roads, sidewalks, parking lots and rooftops made of asphalt, concrete or other materials that impede water infiltration.

Impervious surfaces cause water rerouting and damming and reduce rainfall infiltration, leading to an increase in runoff and flood frequency in urban areas (Shuster et al., 2005). A reduction in water infiltration also lessens groundwater recharge, lowers the water table, and reduces base flows and water availability. In addition, stormwater runoff carries pollutants and pathogens and degrades water quality (Delpla et al., 2009).

Permeable soil holds moisture that reduces heat build-up, while impervious surfaces are a key factor in the urban heat island effect (Deilami et al., 2018). These surfaces therefore have an influence on both the supply of local climate regulation services and water-related services (Table 2).

Given the effects of climate change, such as rising sea levels, rapid spring snowmelts, and extreme weather events like storms and heat waves, the challenges associated with impervious surfaces will increase in the future. Related risks such as floods, water contamination and extreme urban heat events impact human health, public safety and the availability of drinking water.

Earth observation data can be used to measure the proportion of impervious surfaces in total urban area. However, impervious surfaces may be covered by vegetation such as tree canopy, which complicates their measurement. Datasets have been identified that may support the measurement of impervious surfaces. For example, the Automatically Extracted Buildings dataset from Natural Resources Canada (NRCan), using airborne light detection and ranging (LiDAR) data and high-resolution optical imagery, represents the footprints of buildings and could be used to develop a partial measure (NRCan, 2023a). Using similar types of source data, NRCan applies artificial intelligence tools to produce a new series of automatically extracted data called GeoAI, which includes roads and buildings, among other topographic features. Production of the GeoAI Series is incremental, with coverage increasing from year to year (GEO.ca, 2025).

Imperviousness has been estimated using Sentinel high-resolution satellite data (GeoVille, 2018; Statistisches Bundesamt [Destatis], 2023; Sun et al., 2023). Further research will be needed to develop similar estimates for large urban areas in Canada.

Proposed metrics

- Proportion of impervious surfaces in total urban area (percentage)

4.2 Surface water

Surface water in urban areas corresponds to urban blue spaces. The presence of surface water influences the supply of local climate regulation services. It may also confer aesthetic value and enjoyment, and is thus a factor that determines the supply of visual amenity, and recreation and education services (Table 2). The type of water body—for instance, whether it is a lake, a river, a canal or an ocean—also influences ecosystem services.

There is a lack of suitable datasets to track annual and seasonal change in water across Canada's large urban areas. In this absence, the CanVec Series, a topographic dataset containing water features for Canada (NRCan, 2023b), provides basic information on surface water in and around urban areas. CanVec classifies water bodies and watercourses according to 14 classes, including artificial or manmade. It will be used to produce a preliminary estimate of the proportion of surface water in total urban area and to calculate shoreline length.

Many rivers and streams are treated as linear features in CanVec. Previous efforts have applied a 5 metre buffer to obtain a proxy estimate of surface area (Statistics Canada, 2022c). In the future, NRCan's GeoAI Series may be used to measure the presence of surface water (GEO.ca, 2025).

Proposed metrics

- Proportion of surface water in total urban area, by type of water body (percentage)
- Length of shoreline bordering the urban area, by type of water body (metres)

4.3 Temperature and other climatic conditions

The temperature and other climatic conditions of urban ecosystems are changing. Urban temperature is a determining factor for local climate regulation and local biomass provisioning services. At the watershed scale, temperature influences water-related ecosystem services (Table 2).

The annual average temperature in Canada has increased by 2.0°C from 1948 to 2023 (Environment and Climate Change Canada [ECCC], 2024a). Heat waves, which are extreme heat events, are becoming longer and more intense. In urban areas, the impacts of heat waves are amplified by the urban heat island effect, leading to higher temperatures in urban areas, compared with those in surrounding rural areas.

Urban heat islands depend on the configuration and heat-absorbing properties of buildings and streets, the absence or presence of vegetation or water, and heat generated by human activities (Gunawardena et al., 2017; Susca et al., 2011). Therefore, the urban heat island effect varies by neighbourhood (Buyantuyev & Wu, 2010).

Higher temperatures can have numerous impacts on human health and well-being, including general discomfort, respiratory difficulties and heat stroke (Kovats & Hajat, 2008). On average, extreme heat events[7] from 2000 to 2020 caused about 670 excess non-accidental deaths, 115 excess cardiovascular deaths and 115 excess respiratory deaths in Canada's 12 most populated cities combined (Quick, 2024). Older people, young children, people with chronic diseases and people in low-income groups are more vulnerable to the impacts of extreme heat events.

Furthermore, air quality in cities can be worsened by hot and dry weather, which can contribute to increased ozone (O_3) levels and dust. Wildfires are more likely to spread under these conditions, causing impacts from smoke and particulate matter (Jain et al., 2024). Transportation infrastructure can be damaged by extreme summer heat, such as road deterioration from softened asphalt surfaces (Lemmen et al., 2008).

On average, annual precipitation has increased in Canada, especially in the northern part of the country (Zhang et al., 2019). A shift from snow to rain in spring and an increase in the number of days with heavy rainfall in some regions, combined with the expansion of urban areas and associated impervious surfaces, increase the risk of flooding (Vincent et al., 2018).

Rising temperatures and shifts from snow to rain have negative impacts on winter sports, such as ice skating and skiing, and other winter leisure activities (Dickau et al., 2020; Hernandez, 2020). In Alberta, British Columbia and Saskatchewan, winter precipitation decreased from 1948 to 2012 (Zhang et al., 2019).

Several different data sources and methods can be used to calculate temperature and precipitation metrics. The Canada Centre for Mapping and Earth Observation produces monthly and daily air temperature, precipitation and snow water equivalent data from 1950 to 2023, as well as hourly air temperature data for selected years, based on the Ecological Assimilation of Land and Climate Observations model (NRCan, 2024a). Given that this dataset is organized on a 5 kilometre or 10 kilometre resolution grid, depending on the variable, a method must be developed to transpose the data to the scale of large urban areas.

Land surface temperature metrics can be estimated on a finer spatial scale using Earth observation data, such as thermal data from Landsat satellites at a 100 metre resolution. To reduce the effects of inconsistencies caused by cloud cover or the time at which the temperature is captured by the satellite, a three- to five-year average can be calculated. Air temperature could also be modelled using surface temperature from Earth observation data and air temperature data from weather stations (Heris et al., 2021). Weather station data are available in Historical Climate Data (Government of Canada, n.d.).

Proposed metrics

- July and August average daily maximum (daytime) and minimum (nighttime) air temperature (degrees Celsius)
- Three- to five-year average land surface temperature for the peak temperature period, by census tract (CT) or dissemination area (DA) (degrees Celsius)
- Three- to five-year average difference in daytime and nighttime land surface temperature between the urban area and its surroundings for the peak temperature period (degrees Celsius)
- Three- to five-year average difference in daytime land surface temperature between a CT or DA and the whole urban area for the peak temperature period (degrees Celsius)
- Extreme heat events (e.g., number of days when the temperature exceeds a threshold)
- Ancillary metric: Total precipitation, as rain or snow, by season (millimetres per year)
- Ancillary metric: Number of days when rainfall exceeds a threshold (e.g., 99th percentile over all rainy days) (e.g., Yang et al., 2024)

7. Environment and Climate Change Canada's (ECCC's) heat warning criteria were used to define extreme heat events (for more information, see ECCC, 2024b).

4.4 Ambient air quality

Air pollution negatively affects ambient air quality in cities, contributing to premature deaths and other serious health impacts, such as asthma and acute respiratory symptoms. Health Canada (2021a) estimates that air pollution from particulate matter that is 2.5 microns in diameter and less ($PM_{2.5}$), ground-level O_3 and nitrogen dioxide (NO_2) contributes to about 15,300 premature deaths per year in Canada, as well as having non-fatal impacts, with a total economic cost of $120 billion in 2016.

Air quality varies from one city or neighbourhood to another because sources of air emissions are unevenly distributed and air pollutants are affected by local climatic conditions such as wind speed and direction, temperature, and precipitation (Canadian Council of Ministers of the Environment, n.d.).

Outdoor human sources of air emissions include motor vehicles, power generating plants, wood stoves and industrial facilities. Wildfires can also be a significant source of air pollution emissions (Cascio, 2018; ECCC, 2024c; Jaffe et al., 2020). Even trees, which emit pollen and volatile organic compounds (VOCs), can increase the concentrations of $PM_{2.5}$, O_3 and carbon monoxide (CO) at ground level in the presence of sunlight (Harris et al., 2019; Jim & Chen, 2008; Nowak et al., 2018). Some species emit more pollen or VOCs than others (Curtis et al., 2014; Sousa-Silva et al., 2021), but, on balance, trees remove more VOCs than they emit (Zupancic et al., 2015).

Canadian Ambient Air Quality Standards (CAAQS)[8] have been developed for $PM_{2.5}$, O_3, NO_2 and sulphur dioxide (SO_2). From 2006 to 2020, annual average and peak ambient air concentrations of NO_2 and SO_2 decreased at the national level (ECCC, 2024c). The annual average concentration of VOCs decreased from 2006 to 2019. In addition, while the annual average concentration of O_3 remained stable from 2006 to 2020, its average peak concentration decreased. Finally, the annual average and peak concentrations of $PM_{2.5}$ fluctuated from 2006 to 2020, with the highest concentrations recorded in 2018 because of wildfire activity.

Although concentrations of some air pollutants have decreased at the national level in recent years, $PM_{2.5}$ has not followed the same trend (Health Canada, 2021a). $PM_{2.5}$ penetrates deep into the lungs (Health Canada, 2019) and can cause immediate health effects, as well as longer-term impacts on well-being, because it can increase the severity of lung and heart conditions and lead to heart attacks and lung cancer (Cakmak et al., 2018). Ultra-fine particles (100 nanometres in diameter and less) are a subset of $PM_{2.5}$ that have recently been linked to increased risk of mortality from long-term exposure in Canadian cities (Lloyd et al., 2023). The population groups most at risk are children with asthma, older adults and people with existing lung or heart conditions (Health Canada, 2021b).

Based on its National Air Pollution Surveillance Program, ECCC publishes annual average and average peak[9] concentrations of $PM_{2.5}$ for 25 POPCTRs (the provincial and territorial capitals and largest POPCTRs) (ECCC, n.d.-a). For example, the highest average concentrations of $PM_{2.5}$ in 2020 were detected in Québec, Quebec (8.4 micrograms per cubic metre); Windsor, Ontario (7.9 micrograms per cubic metre); Victoria, British Columbia (7.7 micrograms per cubic metre); and Kelowna, British Columbia (7.6 micrograms per cubic metre). These values could be used as proxies to represent the annual average concentration of $PM_{2.5}$ in some large urban areas.

Measures of $PM_{2.5}$ concentration and other pollutants are available from multiple sources. Further research will be required to develop a method of estimating the proposed air quality metrics for large urban areas using available datasets.

Proposed metrics

- Annual average concentration of $PM_{2.5}$ and other pollutants such as NO_2 and O_3 in outside air (micrograms per cubic metre)
- Number of days per year with a concentration of $PM_{2.5}$ and other pollutants in outside air exceeding daily standards (days)
- Ancillary metric: Total air emissions of $PM_{2.5}$ and other pollutants (tonnes per year)

8. The CAAQS were developed by the Canadian Council of Ministers of the Environment as ambient air quality targets to drive air quality management across Canada, under the *Canadian Environmental Protection Act, 1999*. See Canadian Council of Ministers of the Environment (n.d.).
9. “The urban area […] indicators (average and peak [98th percentile] 24-hour) for $PM_{2.5}$ are calculated by averaging the station-level annual average and station-level annual peak values for all stations that met the completeness criteria within […] the urban area […]” (ECCC, 2024c, Data sources and methods).

4.5 Water quality

Urban areas rely on surface water and groundwater sources for drinking water (Trtanj et al., 2016). Water quality, particularly in watersheds upstream of cities, has an impact on water treatment requirements and costs to meet public health needs (Boholm & Prutzer, 2017).

Water quality also affects water-based recreational activities. For example, bacterial or blue-green algae contamination can lead to beach closures. The presence of the bacteria *E. coli* and *Enterococci* in recreational waters indicates fecal contamination that can cause gastrointestinal illnesses, skin infections and other health issues among swimmers.

Clean and abundant water resources are necessary for plant and animal species. Poor water quality can disrupt habitats, reducing the number of fish species thriving in an ecosystem (Doi et al., 2013). A decline in fish species richness may lead to a decrease in fish populations, which may reduce opportunities for activities such as fishing (Dudgeon et al., 2006).

Water bodies become polluted by a range of substances, including pathogenic microorganisms, fertilizers, toxic chemicals, microplastics and sediments. Human activities in urban areas and upstream watersheds influence water quality through direct discharge of waste or diffuse emission of pollutants (Trtanj et al., 2016).

According to the National Pollutant Release Inventory (NPRI), 48,379 tonnes of ammonia and 107 kilograms of mercury were reported to have been released into water bodies in 2023, mainly from waste and wastewater systems (ECCC, 2024d). Ontario (56 kilograms) and Quebec (27 kilograms) had the highest levels of mercury discharged, according to reports. Contaminants such as mercury can enter the food chain, resulting in human health impacts from fish consumption.

In urban areas, runoff from built surfaces and overflow of combined sewer systems during heavy rainfall pollute water and affect aquatic life (Müller et al., 2020). For example, contaminants from tires have been shown to be correlated to the mortality of adult coho salmon in Pacific Northwest streams (Tian et al., 2021). In upstream watersheds, the application of fertilizers such as nitrogen and phosphorus can result in water pollution.

Snow and rainfall also affect water quality by washing accumulated pollutants from roads and fields into rivers and lakes. During droughts, less water is available to dilute pollutants from sources like urban sewage. An increase in the frequency and duration of wet or dry periods associated with climate change will have different effects on water quality, depending on the local conditions (ECCC, 2025).

ECCC maintains various datasets that can be used to measure water quality parameters. The National Long-term Water Quality Monitoring Data (ECCC, 2022) program provides long-term data from sampling sites across Canada and covers parameters such as pH, alkalinity, dissolved oxygen and metals, and nutrients such as nitrogen and phosphorus, although temporal and spatial coverage varies. Water quality parameters, including water temperature, are also monitored every hour for 23 sites across Canada through the Automated Fresh Water Quality Monitoring and Surveillance Data program (ECCC, 2024e). Data reported through the Wastewater Systems Effluent Regulations include discharge point locations, suspended solids, carbonaceous biochemical oxygen demands and effluent discharge volumes (ECCC, n.d.-b). Further research will be needed to integrate these datasets to develop a consistent measure of water quality parameters for large urban areas and upstream watersheds.

As a proxy of water quality in large urban areas, the ratio of pollutants emitted by facilities within the upstream watersheds over the distance of facilities to the urban boundary could be calculated annually using ECCC's NPRI. This proxy could be defined for pollutants such as mineral micropollutants (arsenic, lead, copper and mercury) or nutrients like ammonia, depending on the data available each year.

Indicators of the risk of water contamination by nitrogen and phosphorus for agricultural areas, in Soil Landscapes of Canada, developed by Agriculture and Agri-Food Canada (AAFC), could be used as a proxy to report on water quality. Further research would be needed to refine these indicators to the geographic level of the extended accounting area.

Health Canada's environmental health and safety survey provides guidelines and recommendations for assessing fecal indicators (e.g., *E. coli*) before the start of the swimming season and every week throughout the season in recreational sites (Health Canada, 2022b). The resulting publicly available information—drawn from the websites of municipalities, posted signs and media sources—could be used to compile the concentration of *E. coli* in recreational water bodies in or adjoining large urban areas.

Proposed metrics

- Concentration of *E. coli* in water bodies (colony-forming units per 100 millilitres)
- Water quality parameters (dissolved oxygen, phosphorus and nitrogen) (milligrams per litre or parts per million)
- Proxy: Ratio of pollutants emitted by upstream facilities over the distance of facilities to the urban area (kilograms per kilometre)
- Proxy: Risk of water contamination (risk class)

4.6 Vegetation and green spaces

Vegetation can be found throughout urban ecosystems, from roadside weeds and street trees to gardens and parks. The presence of vegetation is a key aspect in defining urban green spaces and is linked to improvements in urban ecosystem condition and services. Vegetation in cities is affected by land use decisions, but also pest outbreaks, invasive species, air pollution, and climate events such as droughts and ice storms.

Vegetation type, cover, density and health, as well as area configuration, are all important biotic ecosystem characteristics. They help offset the negative effects of impervious surfaces, improve urban air quality, and enhance recreational and amenity values (Bjerke et al., 2006; Ferrini et al., 2020). Vegetation is also an important attribute of wildlife habitat, and vegetation structure has been shown to influence bird biodiversity (Werner, 2011).

Despite the interest in measuring green spaces consistently across large urban areas in Canada, accurately mapping green spaces in cities is not a simple endeavour. Delineating small or linear features, such as street trees or riparian zones, using Earth observation is particularly challenging, given that it requires higher-resolution imagery, which is not easily accessible for a vast country like Canada.

A pan-Canadian dataset with information on the location and delineation of public parks and recreational facilities is currently being developed at Western University (ParkSeek, n.d.). The dataset builds on existing data from municipal and provincial governments, as well as newly created data, and could be used as an input in the measurement of KMGBF indicator 12.1 and UN SDG indicator 11.7.1 when it becomes available.

In the interim, an alternative approach can be taken by using proxy measures for urban green spaces based on vegetation parameters derived from satellite imagery. Over time, additional land use datasets can be used to delineate green spaces. For example, Ju et al. (2022) used Sentinel high-resolution satellite data, in combination with land use data from OpenStreetMap, to map urban green spaces for 371 Latin American cities.

Vegetation parameters, such as the fraction of vegetation cover (FVC), leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FAPAR), measure structural and functional biophysical characteristics of vegetation (see sections 4.6.2, 4.6.3 and 4.6.4). They can be produced for the core or extended accounting areas using NRCan's LEAF Toolbox (Landscape Evolution and Forecasting), an application based in Google Earth Engine that generates vegetation maps from satellite imagery (Fernandes, 2020). This tool uses data captured from May to September each year that can be aggregated for custom periods, such as the peak summer conditions.

Vegetation parameters for urban areas may be difficult to interpret because the resolution of a satellite imagery pixel may be larger than the size of a given land cover in urban areas. Pixel values may be influenced by many factors, including the type of vegetation, the species of plants, their stage of growth and their health. In addition, water, shade, artificial material and climate factors may confound the interpretation of the data.

4.6.1 Vegetation type

The type of vegetation in an area—evergreen or deciduous trees, shrubs, grass or lawns, crops and wetland vegetation—influences the supply of many ecosystem services (Table 2).

Land use and land cover classes based on Earth observation data can be used as a starting point for identifying the types of vegetation growing in urban areas. Data from AAFC's Semi-decadal Land Use Time Series (AAFC, 2023a) and Annual Crop Inventory (AAFC, 2023b) could complement data from Statistics Canada's Land Cover Register (Statistics Canada, 2025a) to help disaggregate vegetated areas according to three vegetation classes within the core or extended accounting areas: cropland; treed areas and treed wetlands; and any other vegetation types, including grasses.

However, the fine-scale mosaic typical of urban areas that results in mixed pixels in Earth observation imagery could lead to misclassifications, for instance, between cropland and settled areas. Further research and testing will be needed to assess the fitness for use of the above-mentioned data or alternative data sources and to identify more detailed vegetation types.

Proposed metrics

- Vegetated areas, by vegetation type (cropland, treed areas and any other vegetation types) (hectares or percentage of total urban area)

4.6.2 Vegetation and tree canopy cover

Vegetation cover includes all areas where vegetation, including trees, shrubs and grass, covers the Earth's surface. A related characteristic, tree canopy cover, is the area of ground covered by tree canopies. It represents the two-dimensional extent of the tree canopy as seen from above. Vegetation cover, and particularly tree canopy cover, can extend over water bodies, bare soil and impervious surfaces such as sidewalks or buildings.

Vegetation cover counteracts the effects of impervious surfaces: it reduces the urban heat island effect, helps rainfall infiltrate into soil and reduces runoff. Trees, in particular, reduce the amount of solar radiation that reaches the ground and intercept rainfall during storm events.

The area of vegetation cover is measured by FVC, the fraction of ground covered by all green vegetation (Fernandes et al., 2023). At a 10 metre or 20 metre resolution, FVC data can be aggregated over CTs or DAs in large urban areas to allow the assessment of environmental inequality (Section 6).

The ideal data sources for measuring tree canopy cover are high-resolution aerial imagery or LiDAR datasets. In the case of LiDAR, a pulsed laser emitted by a scanner installed on an airplane measures the height of objects on Earth with an accuracy of 5 to 10 centimetres (NRCan, 2024b). For example, the canopy for all vegetation higher than 2 metres has been mapped for census metropolitan areas (CMAs) in Quebec using LiDAR data with a 1 metre resolution acquired from 2010 to 2020 (INSPQ, n.d.).

NRCan's LiDAR Point Clouds product integrates LiDAR datasets acquired by NRCan (NRCan, 2024c). The territory covered by LiDAR Point Clouds is gradually increasing as datasets from additional LiDAR projects are integrated. For 19 out of the 30 large CSAs that make up the core accounting area, LiDAR Point Clouds covers more than 75% of the territory, with data available from 2014 to 2023. Additional datasets from municipal, provincial and territorial governments may be available to improve coverage.

ECCC has used a point-sampling approach with photo interpretation to estimate urban tree canopy cover for 2011 in medium and large urban POPCTRs by ecozone-derived geography (Steenberg et al., 2023; Pasher et al., 2014). In addition, NRCan's GeoAI project is developing new methods that may lead to tree canopy cover estimates in large urban areas (GEO.ca, 2025).

Proposed metrics

- Vegetation cover, by CT or DA (hectares or percentage of total urban area)
- Proportion of tree canopy cover in total urban area (percentage)

4.6.3 Vegetation density

Vegetation density can be thought of as the thickness of vegetation, or foliage content, from the ground level up. Together with vegetation and tree canopy cover, it describes the structural state of urban ecosystems (Table 2), but it is also closely related to the functional characteristics of vegetation.

LAI is a vegetation parameter that represents the density and condition of vegetation and is used as a key variable in many studies (Asner et al., 2003). LAI measures the projected area of leaves or upward-facing area, i.e., half the total (upward- plus downward-facing) area of leaves, in square metres of foliage per square metre of ground (Fernandes et al., 2023).

Proposed metrics

- LAI

4.6.4 Vegetation health

Vegetation health reflects plant productivity and photosynthetic activity and is an important functional state characteristic of urban ecosystems. Vegetation health influences the supply of ecosystem services such as local climate regulation and water flow regulation, which involve biological processes like plant transpiration. It also affects the aesthetic value of urban green spaces.

Normalized Difference Vegetation Index (NDVI) images from the Moderate Resolution Imaging Spectroradiometer (MODIS) have been used to monitor urban vegetation condition for all POPCTRs in Canada (Statistics Canada, 2024a). Aggregated over all large urban POPCTRs, average greenness[10] has decreased 10.4 percentage points from the 2000-to-2004 baseline period to the most recent five-year period (2020 to 2024), to 68.2% (Statistics Canada, n.d.-b). This trend might be explained by urban expansion and densification within POPCTR boundaries. Because of the planned decommissioning of the MODIS program, new and improved data sources and techniques are being considered to measure urban vegetation health.

FAPAR will be used to measure the health of vegetation. This vegetation parameter corresponds to the part of photosynthetically active solar radiation that is absorbed by plants, the other part being reflected into the atmosphere (Fernandes et al., 2023). Vegetation that is under stress caused, for example, by exposure to pests, would have a lower photosynthetic activity and a lower FAPAR.

Proposed metrics

- FAPAR (percentage)

4.6.5 Configuration of vegetated areas

Vegetated area configuration is a landscape-level characteristic that refers to the size, shape and connectivity of vegetated patches. Patch configuration influences processes underlying regulating services. Various metrics exist to assess the shape or connectivity of vegetated areas. Examples are the shape index, which measures shape complexity relative to a simple circle, and the sum of the area of urban green that lies within a 50 metre buffer zone of each patch (Chen et al., 2014).

Proposed metrics

- Average size of vegetated areas (square metres)
- Metrics of vegetated area shape or connectivity to be determined

10. Average greenness corresponds to the percentage of land with an NDVI of 0.5 or more (for more details, see Statistics Canada, n.d.-b).

4.7 Biodiversity

People have considerable influence on the types and abundance of species found in urban areas (Kowarik, 2011; Schwarz et al., 2017; Spotswood et al., 2021). For instance, management practices and choices about the types of grasses and plants to grow in parks and yards, and the removal of weeds, have direct and indirect impacts on the diversity of plants in urban areas and the species they interact with (e.g., pollinators, microorganisms and herbivores) (Avolio et al., 2021).

While some species avoid urban areas, many use and occupy different urban habitats (Fischer et al., 2015). Many species found in urban areas are native species that take advantage of remnant habitat patches, while others (including non-native species) have improved reproductive success or survival in urban areas (Spotswood et al., 2021). For instance, some bird species have been found to have better survival rates in urban areas, compared with rural areas (Evans et al., 2015).

The relationship between biodiversity and the supply of ecosystem services in urban areas is likely to be different from that in non-urban areas (Schwarz et al., 2017). Despite a growing scientific literature on the topic, there remain important gaps in understanding urban species' role in the supply of ecosystem services (Rega-Brodsky et al., 2022; Ziter, 2016).

This framework includes proposed measures for bird biodiversity and pollinator abundance as relevant characteristics of urban ecosystems. Further research will be needed to measure biodiversity in urban areas on a national scale. Chosen metrics should reflect the abundance and species richness of native, non-native and functional groups of species that directly support ecosystem service supply.

Data from crowdsourced platforms such as eBird and iNaturalist are a potentially useful source of information on species diversity. These databases provide access to species observation data across large spatial and temporal extents (Mair & Ruete, 2016; Rega-Brodsky et al., 2022). Achieving this level of coverage through planned scientific surveys is difficult in a country the size of Canada.

However, when it comes to producing robust statistics, limitations inherent to this type of data must be addressed. Errors, missing metadata, and spatial and preference biases can lead to the overrepresentation of popular species and more accessible areas and can result in skewed estimates of species populations (Fraisl et al., 2022; Johnston et al., 2023; Mair & Ruete, 2016). Further research on ways to address or mitigate these limitations will be required for these data sources to be used effectively.

4.7.1 Bird biodiversity

Many urban residents enjoy viewing, hearing or feeding birds (Perry et al., 2020). In 2023, 22% of Canadian households in all CMAs made purchases to feed, shelter or watch birds (Statistics Canada, 2025b). Therefore, bird biodiversity has a role in recreation and education services. However, not all species are appreciated equally, with some even posing a risk to human health and safety. For instance, Canada geese can cause damage to vegetation, degrade water quality and be aggressive toward people.

Because birds are often at the top of the food chain, monitoring bird populations is an effective way of tracking changes in biodiversity (Fraixedas et al., 2020; Gregory, 2006). Overall, generalist bird species are more abundant in urban areas, compared with specialist species that depend on specific resources and habitat conditions for survival (Zulian et al., 2022). Urban areas in temperate zones tend to benefit omnivorous, granivorous and cavity-nesting bird species (Lepczyk et al., 2017).

On the city scale, the extent, proportion and connectivity of vegetated and riparian areas tend to have a positive impact on the richness, abundance and density of bird species (Lepczyk et al., 2017; Zulian et al., 2022). However, these same measures may vary differently across green and blue areas within the city, thereby indicating that they should be considered simultaneously for a better understanding of bird diversity in urban areas (Thompson et al., 2022). Additionally, research has shown that changes to vegetation cover may take years to be reflected in the characteristics of urban bird populations (Dallimer et al., 2015).

Data from crowdsourced initiatives could be used to measure bird abundance, species richness or other relevant biodiversity metrics, depending on future assessment of their limitations and fitness for use.

Proposed metrics

- Bird richness, diversity or presence of keystone species

4.7.2 Pollinator abundance

Pollinators such as bees, butterflies, birds and bats fertilize many plants, including vegetable- and fruit-bearing plant species. They support local biomass provisioning and help maintain or increase the abundance and diversity of other species. Pollinators perform an important ecological role, and their abundance is considered a functional condition characteristic of urban ecosystems (United Nations et al., 2021).

Urbanization may have a mixed impact on pollinators. In general, urban areas have lower levels of pollinator biodiversity than natural areas. However, urban areas can also act as a refuge for pollinators when the adjacent agricultural areas are exposed to high rates of pesticide use. The availability of nesting sites and materials, the presence of native and non-native flowering plants, and the overall amount of green space in urban areas can make for more hospitable conditions for many species (Hall et al., 2016; Wenzel et al., 2020).

Data from crowdsourced initiatives could be used to measure pollinator abundance, depending on further assessment of available data and their fitness for use in urban areas.

Proposed metrics

- Pollinator abundance (including native species)

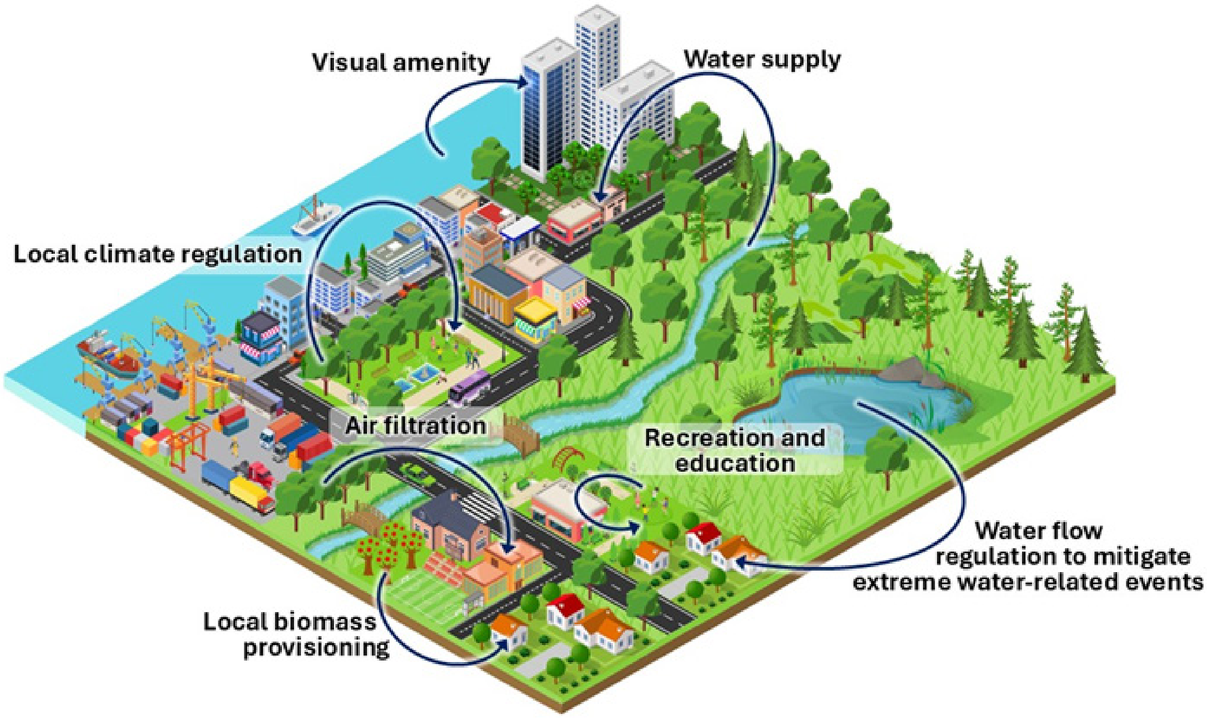
5 Ecosystem services

Following the SEEA EA, ecosystem services are the contributions of nature to people (United Nations et al., 2021). The supply of ecosystem services to the people who live or work in urban areas depends on the extent and condition of the urban ecosystem and nearby natural, semi-natural and agricultural ecosystems (sections 3 and 4). These services can reduce the impacts of environmental hazards, enhance adaptation to adverse environmental conditions, and improve physical and mental health.

Ecosystem services are particularly valuable in large urban areas because they help offset urban-specific environmental issues that affect a majority of Canadians. For example, the many sources of air pollution in cities, coupled with a dense population, translate into greater benefits associated with air pollution removal in urban areas, compared with rural ones (Nowak et al., 2014).

Urban ecosystems generate multiple services, but ecosystems at all spatial scales—from local to global—provide services to urban populations (Gómez-Baggethun et al., 2013). This framework focuses on seven final ecosystem services that have direct impacts on the well-being of people who live or work in urban areas (Figure 1). Other services supplied by nature in cities, such as noise attenuation and global climate regulation through carbon sequestration and storage, are not covered. An ecosystem service is considered “final” when it directly benefits humans and “intermediate” when it contributes to the supply of a final ecosystem service.

Figure 1
Selected ecosystem services for large urban areas in Canada



Source: Statistics Canada, Environment Accounts and Statistics Division.

The SEEA EA classification of ecosystem services includes three types of services: provisioning, regulating and cultural services.

- Provisioning services reflect ecosystem contributions to products extracted or harvested from ecosystems. These include nature's contributions to crops harvested from community gardens and water supplied by watersheds.
- Regulating services refer to the capacity of ecosystems to maintain climatic, hydrological and biochemical cycles, as well as biological processes. In urban ecosystems, vegetated surfaces help mitigate the impacts of extreme weather events and hazards, such as storms and floods, by absorbing water and mitigating peak flow.
- Cultural services are generated through various forms of human interaction with nature, where physical setting, location and characteristics of ecosystems give rise to emotional, intellectual and symbolic benefits. For cultural services to be realized, the perceived qualities of spaces are as important as the actual characteristics of ecosystems (Buchel & Frantzeskaki, 2015; Dickinson & Hobbs, 2017). Recreation, knowledge development, relaxation, aesthetic appreciation and spiritual reflection are a few examples of how humans derive cultural benefits from ecosystems.

Based on the SEEA EA and scientific literature, a logic chain for each selected ecosystem service presents the sequence of information starting with common ecosystem assets that supply the service (Table 3) and ending with the main users and beneficiaries of the ecosystem service (Table 4). Many ecological factors determining supply are ecosystem condition characteristics that are described in this framework (Table 2).

Table 3
Common assets supplying selected ecosystem services for large urban areas in Canada

Ecosystem services	Service type	Common assets in urban ecosystem or immediate upstream watersheds
Supplied mostly by the urban ecosystem		
Air filtration	Regulating	All urban green spaces, particularly trees and shrubs
Local climate regulation	Regulating	All urban green and blue spaces, particularly trees
Local biomass provisioning	Provisioning	For crop provisioning: Community and residential gardens; croplands in and adjoining urban areas
Recreation and education	Cultural	Green and blue spaces for public use in and adjoining urban areas
Visual amenity	Cultural	Green and blue spaces in and adjoining urban areas
Supplied mostly by the immediate upstream watersheds		
Water supply	Provisioning	Inland water bodies and natural and semi-natural terrestrial ecosystems within upstream watersheds, particularly wetlands and riparian areas; permeable soil and vegetated assets in urban ecosystems
Water flow regulation to mitigate extreme water-related events	Regulating	Vegetated natural and semi-natural assets within upstream watersheds or urban ecosystems, particularly riparian areas, wetlands and water bodies; green engineered elements such as green roofs, bioswales and permeable pavement

Source: Statistics Canada, Environment Accounts and Statistics Division.

Table 4
Logic chains for selected ecosystem services

Ecosystem services	Ecological factors determining supply	Societal factors determining supply	Factors determining use	Physical metrics for the ecosystem service	Benefits	Main users and beneficiaries
Supplied mostly by the urban ecosystem						
Air filtration	• Precipitation[1] • Wind • Ambient air quality (pollution)[1] • Vegetation type[1] • Vegetation and tree canopy cover[1] • Vegetation density[1] • Tree canopy height • Vegetation health[1] • Configuration of vegetated areas[1]	• Air emissions[1]	• Population exposed to pollution • Outdoor activities	• Removal of fine particulate matter and other pollutants such as nitrogen dioxide and ozone • Relative air quality improvement	• Health benefits from reduced exposure to air pollutants • Reduced damage to built physical components of cities	• Households • Governments (health service providers, building owners) • Businesses (building owners)
Local climate regulation	• Impervious surfaces[1] • Surface water[1] • Temperature[1] • Wind • Type of vegetation[1] • Vegetation and tree canopy cover[1] • Vegetation density[1] • Vegetation health[1] • Configuration of vegetated areas[1]	• Surface albedo • Management practices on trees	• Population exposed to high temperature • Distance to green or blue spaces • Public perception and education	• Reduction in maximum air temperature • Number of people benefiting from reduced air temperature on hot days • Reduction in cooling energy costs	• Improved living conditions from reduced air temperature • Reduction in illnesses or excess deaths caused by extreme heat events	• Households • Governments (employers, health service providers) • Businesses (employers, insurers)
Local biomass provisioning	• Temperature[1] • Precipitation[1] • Insectivorous bird and bat abundance (for pest control) • Pollinator abundance[1] • Water supply	• Cultivation practices (e.g., fertilization) • Soil contamination • Regulations limiting cultivation	• Demand for locally grown food • Presence of local distribution channels • Recreational value of gardening	• Locally harvested biomass attributable to ecosystem contribution • Proxy: Total locally harvested biomass • Proxy: Average operating revenues from direct sales of farms • Proxy: Urban green spaces, by use	• More accessible vegetables and fruits • Fresher vegetables and fruits • Health benefits through improved diet	• Households (for own consumption or as buyers) • Local farmers

Table 4
Logic chains for selected ecosystem services

Ecosystem services	Ecological factors determining supply	Societal factors determining supply	Factors determining use	Physical metrics for the ecosystem service	Benefits	Main users and beneficiaries
Supplied mostly by the urban ecosystem						
Recreation and education	• Precipitation (snow)[1] • Surface water[1] • Ambient air quality[1] • Water quality[1] • Vegetation type[1] • Vegetation and tree canopy cover[1] • Tree canopy height • Vegetation health[1] • Bird biodiversity[1]	• Built structures enabling recreation (e.g., walking paths) • Maintenance practices (e.g., general upkeep) • Absence of intrusive noise • Presence of businesses supplying goods and services for recreation (e.g., restaurants)	• Accessibility of green and blue spaces • Safety • Demand for outdoor recreation • Outdoor classes, workshops and excursions by local educational organizations	• Number of visits to public green and blue spaces, by season • Population with access to public urban green and blue spaces • Length of stay in public green and blue spaces, by season • Schools with access to public green and blue spaces	• Enjoyment • Improved physical and mental health • Improved cognitive function • Intellectual development	• Households • Children and youth • Educational organizations
Visual amenity	• Surface water[1] • Water quality[1] • Vegetation type[1] • Vegetation and tree canopy cover[1] • Tree canopy height • Vegetation health[1] • Bird biodiversity[1]	• Maintenance practices (e.g., general upkeep)	• Landscaping preferences • Location and design of residential and office buildings • Demand for housing near green and blue spaces	• Number of residential and office buildings located near green and blue spaces • Population residing near green and blue spaces • Premium on property values or rental values arising from proximity to green and blue spaces	• Enjoyment • Improved mental health • Improved cognitive function • Increased property value	• Households • Building owners
Supplied mostly by the immediate upstream watersheds						
Water supply	• Impervious surfaces[1] • Temperature[1] • Precipitation[1] • Evapotranspiration and aridity index • Water quality[1] • Vegetation type[1] • Vegetation and tree canopy cover[1] • Vegetation biomass[1] • Vegetation health[1] • Vegetation age • Configuration of vegetated areas[1] • Soil properties • Topography	• Management practices in watershed (e.g., reforestation, wetland restoration, dams, artificial reservoirs) • Soil contamination • Water emissions and pollution loads from runoff • Water treatment	• Demand for good-quality water at different times of year • Per capita water consumption • Industrial and agricultural activities • Regulatory constraints over water use and pricing mechanisms	• Total volume of water abstracted for use by households and industry • Amount of drinking water used by residential and non-residential sectors • Proxy: Annual water yield	• Reduced need for other forms of water storage • Reduced need for extensive water treatment • Water use (e.g., by drinking water plants and households, for irrigation and hydroelectricity generation, as industrial inputs) • Water quality improvement for recreation and aquatic biomass provisioning	• Drinking water plants • Households • Industry (e.g., agriculture)
Water flow regulation to mitigate extreme water-related events	• Impervious surfaces[1] • Temperature[1] • Precipitation (storms)[1] • Evapotranspiration and aridity index • Vegetation type[1] • Vegetation and tree canopy cover[1] • Vegetation density[1] • Vegetation health[1] • Configuration of vegetated areas[1] • Land use and degradation • Soil properties • Topography	• Management practices in watershed (e.g., reforestation, wetland restoration, erosion management)	• Extent of produced assets for regulating water flow • Location of properties	• Stormwater retention volume • Stormwater retention to total water volume during peak flows • Rainfall interception by urban trees to total water volume during peak flows • Number of people benefiting from reduced flood risk	• Reduced protection and damage costs • Reduced physical and mental health impacts	• Households • Businesses (building owners) • Governments (building owners)

1. Priority measurement variable (see Table 2).
Source: Statistics Canada, Environment Accounts and Statistics Division.

Features of urban ecosystems, such as vegetation, may have positive effects on the supply of numerous ecosystem services. For instance, dense vegetation is associated with a higher rate of pollution removal and a greater cooling effect. However, these same features may bring about disservices, for example, the trapping of heat that radiates from built up surfaces at night or damage from falling branches during storms. These negative effects may appear in the accounts as diminished ecosystem condition or a reduced flow of ecosystem services (United Nations et al., 2021).

This framework focuses on biophysical measurement of ecosystem services. Measuring ecosystem services is challenging, even when data are readily available. The supply and use of ecosystem services are often estimated using modelling tools or are represented by proxies. Pilot ecosystem service accounts will include experimental measures of supply or use, with explicit recognition of data gaps. Typically, measuring cultural services is more difficult than measuring regulating services, which are in turn more difficult to measure than provisioning services (Gómez-Baggethun et al., 2013).

5.1 Ecosystem services supplied by the urban ecosystem

Within the urban ecosystem, the assets supplying ecosystem services are the green and blue spaces, such as vegetated and permeable areas, trees, and water bodies. Services supplied by local urban green and blue spaces often directly contribute to health and security benefits (Gómez-Baggethun et al., 2013). Most areas that are classified as grey, such as parking lots, do not supply ecosystem services.

5.1.1 Air filtration

Air filtration services represent the removal of airborne pollutants through deposition, uptake, transformation and storage by ecosystem components, particularly plants (United Nations et al., 2021). Although emissions of air pollutants in cities often exceed the capacity of urban vegetation to remove them (Zupancic et al., 2015), vegetation reduces ambient concentrations of pollutants in a measurable way and mitigates their negative health effects (Section 4.4).

In urban areas, air filtration services are supplied primarily by urban green spaces, as well as vegetation adjacent to urban areas. Urban trees, forests, parks and agricultural areas all contribute to these services. Green walls and roofs also contribute, but evidence on their effectiveness is mixed (Abhijith et al., 2017; Zupancic et al., 2015).

Air pollution removal has been most studied with respect to $PM_{2.5}$ and particulate matter that is 10 microns in diameter and less because of their disproportionate impacts on human health (Harris et al., 2019). Other pollutants have also been modelled, including O_3, NO_2, SO_2 and CO.

Air filtration services are provided primarily by two mechanisms: (1) internal absorption by plants and (2) deposition of particles on surfaces, such as leaves and bark (Harris et al., 2019; Jim & Chen, 2008; Nowak et al., 2018). Air pollution removal rates thus depend on a combination of vegetation characteristics (e.g., proportion of deciduous and evergreen trees, vegetation density and health, leaf on and off dates), meteorology (e.g., air temperature, precipitation, wind speed, solar radiation, humidity) and local pollution concentrations (Zupancic et al., 2015) (Table 4). Air pollutants can also damage plants, so while air pollution is removed at a faster rate with a higher concentration, it can also deteriorate vegetation health and reduce the future capacity for air filtration.

Pollution removal is higher with more foliage and a denser canopy and varies by species and by pollutant (Nowak et al., 2018; Zupancic et al., 2015). Trees and shrubs remove more pollution than smaller plants (Harris et al., 2019). In general, particulate removal is higher for coniferous trees than evergreen broadleaf trees and lower for deciduous trees (Han et al., 2020). Nevertheless, broadleaf trees have been found to remove more atmospheric O3 than conifers (Alonso et al., 2011, as cited in Zupancic et al., 2015). Therefore, a higher diversity of tree species may offer complementary air pollution removal effects.

Although tree canopies can prevent pollution from the upper atmosphere from reaching ground level (Nowak et al., 2018), vegetation can also trap pollution from local emission sources, increasing local concentrations (Harris et al., 2019; Zupancic et al., 2015). The "canyon effect" created by street trees and buildings can reduce air circulation that would otherwise transport traffic pollution away (Abhijith et al., 2017; Kumar et al., 2019). Trees can also emit pollen and VOCs. Thus, even while trees are removing pollution from the air, the resulting local ambient concentrations and exposure may vary.

While the supply of air filtration services is measured in terms of pollution concentrations, the use and benefits of air filtration depend on the presence of people and their level of exposure to pollutants being filtered. A person's exposure to air pollution can also be affected by their behaviour, particularly their participation in outdoor activities (Nowak et al., 2018). Air pollution exposure is ultimately the product of a complex interaction of several factors, some of which are difficult to capture in large-scale estimates of air pollution removal (Harris et al., 2019; Zupancic et al., 2015).

Air filtration services provide two main benefits to society: improved health, and reduced damage to buildings and other built components of cities (Harris et al., 2019). Air pollution, especially particulate matter, contributes to elevated all-cause risk of mortality and acute respiratory symptoms, such as asthma (Cascio, 2018; Health Canada, 2021a; World Health Organization, 2021). Air pollution removal reduces these impacts, leading to fewer premature deaths and respiratory symptoms, and lower health care costs (Elmqvist et al., 2015; Nowak et al., 2018).

The main beneficiaries of reduced health impacts from air pollution removal are urban households, as well as people who work in urban areas. Air filtration services are associated with environmental inequality issues because pollution sources and the vegetation that removes pollution may be distributed unevenly within an urban area, relative to socioeconomic factors such as income (Elmqvist et al., 2015; Zupancic et al., 2015).

Metrics for physical ecosystem service flows include both the absolute quantity of pollution removed and the percentage change in pollution concentration, to account for the fact that pollution removal increases with pollution concentration (Harris et al., 2019; Nowak et al., 2018). Pollution removal is best measured separately for each pollutant to consider different rates and benefits associated with each type. For example, the health benefits of removing particulate matter are much greater than those associated with removing other pollutants. To measure air filtration as an ecosystem service, the amount removed is measured relative to a counterfactual of "no vegetation" (e.g., bare soil or water) (United Nations et al., 2021).

National-scale studies across multiple cities combine data from remote sensing and monitoring programs into computer models to estimate air pollution removal per unit area and time (Nowak et al., 2006; Nowak et al., 2014; Nowak et al., 2018). The i-Tree suite of modelling tools, developed by the United States Department of Agriculture (USDA) Forest Service (Nowak, 2024), is often used in these studies to integrate data into models and calculate estimates for study areas.

Nowak et al. (2018) combined local environmental data and computer simulations in i-Tree to estimate between 7,500 to 21,100 tonnes of air pollution (CO, NO_2, O_3, $PM_{2.5}$ and SO_2) removed across 86 Canadian cities in 2010. This suggests that it would be feasible to reproduce such estimates for large urban areas in Canada across multiple accounting periods.

Proposed metrics

- Removal of $PM_{2.5}$ (grams per square metre per year, aggregated to tonnes per year over core accounting area) and other pollutants such as NO_2 and O_3
- Air quality improvement ($PM_{2.5}$ and other pollutant removal / [concentration + removal]) (percentage)

5.1.2 Local climate regulation

Local climate regulation services correspond to the regulation of ambient atmospheric conditions through vegetation and other ecosystem components (United Nations et al., 2021). This framework focuses on reductions in temperature associated with heat waves and urban heat island effects in cities (Section 4.3). Lower temperatures during extreme heat events improve living conditions and reduce health impacts for people who live and work in urban areas (Iungman et al., 2023).

Local climate regulation occurs through shading, with tree canopy cover blocking solar radiation that would otherwise heat built surfaces. Evapotranspiration from water surfaces, vegetation and permeable soil, which holds moisture, consumes heat energy in the local environment, leading to reduced air temperature (Heris et al., 2021; Winbourne et al., 2020).

Vegetation within the urban ecosystem, from larger urban green spaces to yards and trees, supplies local climate regulation services. Areas with trees, gardens, lawns and green engineered elements such as green roofs help regulate the local climate. Water bodies, such as lakes and rivers, also supply these services (Babí Almenar et al., 2021; Deilami et al., 2018; Ignatieva et al., 2020).

The type of vegetation (e.g., coniferous or deciduous trees, shrubs, grass) or water body, vegetation density and health, and the configuration of vegetated areas affect the supply of local climate regulation services (Chen et al., 2014; Deilami et al., 2018; Winbourne et al., 2020). For instance, irregularly shaped vegetated patches contribute more to lowering temperature than circular patches. The cooling processes operate at various spatial levels (Kong et al., 2014) and vary with season and between daytime and nighttime (Table 4).

Local climate regulation services come into play if people who are exposed to extreme heat where they reside, work or carry out activities also benefit from the proximity to urban green or blue spaces, such as street trees (United Nations et al., 2021). People who live in urban households or work in urban areas are the beneficiaries of the improved conditions and reduced health impacts resulting from these services. Households and businesses equipped with air conditioning are less exposed to heat but may still benefit from local climate regulation in the form of reduced energy costs associated with cooling (Heris et al., 2021).

Heris et al. (2021) modelled heat mitigation at a 30 metre resolution for 768 municipalities in the United States based on tree canopy cover and impervious surfaces, using Landsat surface temperature and air temperature data from weather stations. In a two-step approach to measure the cooling energy savings supplied by trees relative to a scenario without trees, they linked canopy cover and impervious surfaces to surface temperature, and surface temperature to air temperature.

Proposed metrics

- Reduction in maximum air temperature compared with non-serviced areas (degrees Celsius)
- Number of people benefiting from reduced air temperature on hot days (counts)
- Reduction in cooling energy costs compared with non-serviced areas (dollars)
- Reduction in excess deaths caused by extreme heat events (counts or percentage)

5.1.3 Local biomass provisioning

Biomass provisioning services are the contributions from ecosystems to harvested products (United Nations et al., 2021). Local crop provisioning is the focus of the work on biomass provisioning services in large urban areas in Canada. Fish and shellfish harvesting from urban blue spaces, as well as food foraging or forest product gathering from urban green spaces, could also be included as part of provisioning services.

In the urban context, local crop provisioning services are associated with urban and peri-urban agriculture, defined as “the production of food and other outputs and related processes, taking place on land and other spaces within cities and surrounding regions” (Food and Agriculture Organization et al., 2022, p. 11). It is recognized that urban and peri-urban agriculture can help safeguard food security, including access to nutritious food (Khan et al., 2020; Haberman et al., 2014). The ecosystem accounts for large urban areas in Canada cover intra-urban agriculture, which takes place in the urban area, as well as peri-urban agriculture, which takes place on land adjoining the urban ecosystem.

A variety of green assets can supply local crop provisioning services. For example, small plots for self-consumption, including community and residential horticultural gardens or orchards, as well as green engineered elements such as green roofs, support crop production (Babí Almenar et al., 2021; Khan et al., 2020). On farmland in and adjoining urban areas, local farmers produce vegetables, fruits and other edible plant parts, which can be made accessible to the urban population through direct sales, such as community-supported agriculture.

Crop provisioning services are nature's contributions to the harvested biomass. They correspond to the proportion of a harvest that can be attributed to ecosystem processes, excluding human inputs such as labour and fertilizer or pesticide application. Greenhouse crops are excluded because of the low level of ecosystem contribution to the produced biomass.

The supply of local crop provisioning services depends on various ecological factors, such as temperature and pollinator abundance, which influence these processes. Societal factors include cultivation practices (e.g., in the ground or in containers), as well as regulations limiting cultivation, soil contamination or other constraints (Grafius et al., 2020).

Use of local crop provisioning services depends on the demand for locally grown food and presence of local distribution channels. Local crop provisioning is also stimulated by recreational values such as the enjoyment of gardening. In 2021, 59% of households in CMAs reported growing fruit, herbs, vegetables or flowers for personal use (Statistics Canada, 2023e). Other research suggests that half of Canadians grow at least one type of fruit or vegetable in a home garden and that one-quarter of home gardeners live in the urban core of cities (Mullins et al., 2021).

One study about gardening on the Island of Montréal indicated that, for 10% of gardeners, more than 50% of the fruits, vegetables and herbs they consumed during the summer came from their own production in 2013 (Ville de Montréal, 2022). Although only a small share of the food consumed by the urban population is supplied by assets in and adjoining urban areas (Gómez-Baggethun et al., 2013), most crops that are grown locally are fresher because they are harvested at home or have shorter storage and delivery times.

Local crop provisioning services should be measured by tonnes of locally harvested biomass attributable to ecosystem contribution. In the absence of information about the proportion attributable to natural inputs, total harvested biomass can be used as a proxy to measure crop provisioning services. However, data on harvests at local scales are not readily available, even for commercial farming, and would have to be modelled from existing national datasets.

The Census of Agriculture includes the percentage of farms' total operating revenues from direct sales for 2021, by census consolidated subdivision. In Canada, 25,917 farms reported direct sales, including sales through on-site or off-site farm stores, farmers' markets and community-supported agriculture (Statistics Canada, 2022d). Of these farms, 13,214 reported deriving more than 50% of their operating revenues from direct sales. These data could potentially be used to estimate the average operating revenues from direct sales of farms in or adjoining urban areas.

Among households in CMAs that reported growing fruits, herbs, vegetables or flowers for personal use, 71% did so in their yard and 2% did so in community gardens (Statistics Canada, 2023e). This suggests that measuring yard area could be a proxy for the potential supply of local crop provisioning services. Urban green spaces could be classified by use, including commercial cropland, yards, community gardens and informal spaces, although developing a method to do this will require further research.

Proposed metrics

- Locally harvested biomass attributable to ecosystem contribution (tonnes per square metre)
- Proxy: Total locally harvested biomass (tonnes per square metre)
- Proxy: Average operating revenues from direct sales of farms in or adjoining urban areas (dollars)
- Proxy: Urban green spaces, by use (e.g., commercial cropland, yards, community gardens, informal spaces) (square metres or percentage of total urban area)

5.1.4 Recreation and education

Recreation and education services refer to the enjoyment that people derive from physical, experiential or intellectual interactions with the environment (United Nations et al., 2021). Even though the SEEA EA distinguishes recreation services from education services, they are covered together in this framework because of similarities in the factors that affect their supply and use. There is also potential overlap between the two services because recreational and educational activities are not mutually exclusive (Mocior & Kruse, 2016).

Recreational and educational activities can occur in a variety of settings, from urban woodlands to public parks, vegetated plazas, beaches and waterfronts, lakes, rivers, and canals. Some activities are more dependent on the characteristics of natural environments (e.g., bird watching, hiking, fruit picking). For instance, the diversity of flowers and pollinators observed in meadows offers greater educational value, compared with lawns in public parks (Paudel & States, 2023).

The supply of recreation and education services depends on a range of human inputs that enable access to and enjoyment of green and blue spaces (Barton et al., 2019). This includes built features such as walking and cycling paths, information boards, playgrounds for children, sport facilities, toilets, and drinking fountains (van den Berg, P. et al., 2022; Wolff et al., 2022). Activities to restore and maintain green and blue spaces are important because they impact safety, physical access and the overall quality of these spaces (United Nations et al., 2021). On-site businesses such as restaurants and equipment rental providers might also support or facilitate the supply of recreation services. In the case of education ecosystem services, offerings of outdoor classes, workshops and excursions by local educational organizations are a determining factor (Mocior & Kruse, 2016).

In Canada, seasons have a major effect on the recreational potential of outdoor spaces as they enable specific types of recreational activities. In the fall, many people enjoy the changing colours of trees while out in nature. In the summer, parks and green spaces are used for many sports activities, while lakes, rivers and ocean shores are used for swimming, kayaking and surfing. In the winter, these same areas may be used for sledding, skating or cross-country skiing.

There is a strong link between user perception and the suitability of green and blue spaces for recreational and educational activities. In particular, the recreational and educational potential of these spaces can be seen as a spectrum, where the natural and infrastructural characteristics of a site make it possible for people to do different activities and learn about different topics (Barton et al., 2019; Massoni et al., 2018). For example, some people will see potential for recreation in any grassy open space, though that same space may be perceived as uninviting by others. A study found that a “high amount of green” was considered important by people who reported using green and blue spaces for walking, cycling, jogging, relaxing, observing nature, walking their dog, and eating and drinking (Krellenberg et al., 2021). Other reported attributes include the diversity of plant and animal species and the presence of trees, meadows, forest areas and water elements.

Because recreation- and education-related activities occur in situ, the accessibility of green and blue spaces is an important factor that affects use (United Nations et al., 2021). Accessibility encompasses access points, distance, travel options and access rights. While the spatial distribution of access points has an impact on walkable distance, access to public transportation is important for reaching a larger pool of users. Persons with mobility-related disabilities can benefit from accessible access points and public transport options (Wolff et al., 2022). Local regulations can also affect who has access and how green and blue spaces are used. For instance, some cities prohibit the use of barbecues in public parks. Additionally, cities may be tempted to increase population density around urban parks to increase access to these spaces. This in turn increases the risk that these spaces will be perceived as overcrowded (Arnberger, 2012).

Green and blue spaces provide opportunities to engage in healthy recreational behaviours and social interactions, which have a positive impact on various aspects of physical and mental health across all stages of life. Some benefits related to recreation services may even be experienced before birth—increased visits of pregnant mothers to green spaces have been associated with lower risks of preterm birth and infant mortality (Douglas et al., 2017). Ngom et al. (2016) found that proximity to green spaces equipped with sports facilities was correlated with lower prevalence of diabetes and cerebrovascular diseases. Exposure to vegetation can also help with cognitive functions such as concentration and memorization, further increasing the relevance of using green and blue spaces as learning environments (Vella-Brodrick & Gilowska, 2022).

Metrics for recreation ecosystem services, and cultural ecosystem services in general, usually reflect the type, number or quality of interactions people have with ecosystems (United Nations et al., 2021). Visits to green and blue spaces are considered a good indicator of recreation ecosystem service flows (Barton et al., 2019; Hermes et al., 2018). Population surveys can be used to collect both quantitative and qualitative information on visits to urban green or blue spaces.

At Statistics Canada, the Households and the Environment Survey collects data on participation in outdoor activities close to home[11] (including the type of activity), visits to parks located close to home and visits to parks not located close to home. Data are currently disseminated at the CMA level. Another way researchers measure rates of visits is by using geolocated data from smartphone users or social media posts and tags (Barton et al., 2019; Hermes et al., 2018).

When visit data are not available, potential visits can be estimated based on the number of people living within an accessible distance. This approach connects with KMGBF indicator 12.1, which measures the share of land allocated to spaces for public use for all.[12] To delineate the accessible area, it is recommended to use a maximum distance of 400 metres from green and blue spaces along the local street network (United Nations Environment Programme World Conservation Monitoring Centre, 2024). The same method can be used to indirectly measure education services by focusing on schools within walking distance of green and blue spaces.

Measures of proximity to neighbourhood parks are already available at the dissemination block level through the Proximity Measures Database and could be used to estimate the number of people living within a 1 kilometre network distance to a park (Statistics Canada, 2023f). Additionally, the Spatial Access Measures dataset (Statistics Canada, 2023g) provides a measure of access to recreational facilities and educational facilities by mode of transport (walking, biking and public transit).

Length of stay, measured using smartphone GPS tracking, has been suggested as an indicator of perceived quality (Barton et al., 2019), based on the logic that the longer people stay in a park, the likelier it is to offer quality recreation and education opportunities.

Proposed metrics

- Number of visits to public green and blue spaces, by season (count)
- Population with access to public urban green and blue spaces (count and proportion)
- Length of stay in public green and blue spaces, by season (minutes)
- Schools with access to public green and blue spaces (count and percentage)

5.1.5 Visual amenity

Humans experience nature through their senses. Positive experiences of nature can have a restorative effect on the mind and contribute to a general sense of well-being (Stoltz & Grahn, 2021). For instance, natural sounds like those of water, wind in the trees and birdsong have been linked to improved well-being (Fisher et al., 2021).

Visual amenity services emphasize the visual impact that nature has on people, without any requirement to engage actively. The SEEA EA defines visual amenity services as “the ecosystem contributions to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual” (United Nations et al., 2021, p. 148).

Landscape architects use trees and other vegetation to improve the visual appearance of cities. Variations in vegetation type, density, size, shape and colour appeal to the senses and can be used in landscaping to integrate buildings with their surroundings and make outdoor spaces more attractive (Tyrväinen et al., 2005). Nevertheless, landscaping is not a prerequisite for the aesthetic appreciation of nature; people may prefer wild vegetation (e.g., untended meadows) over managed green space when they are informed of the ecological benefits (de la Fuente de Val, 2023).

Assets providing visual amenity services range from street trees and managed vegetation in public parks and on private properties to wild vegetation growing on undeveloped parcels. Among the different types of urban green assets, trees stand out for their size, shape and seasonal change of colour (Tyrväinen et al., 2005). They are widely appreciated by urban residents (Conway et al., 2024) and are at the centre of many municipalities’

11. In the context of this survey, “close to home” is broadly defined as being within a 10 minute journey from home.
12. Identifying public spaces comes with specific challenges (United Nations Environment Programme World Conservation Monitoring Centre, 2024), and further work will be necessary to find the best approach to determine the public accessibility of green and blue spaces. Potentially useful data sources include property assessment data from the Canadian Housing Statistics Program and open data from OpenStreetMap.

greening strategy. In particular, the “3-30-300” guideline for urban forestry recommends that a minimum of three trees should be visible from every home, school and place of work; that tree canopy cover be at least 30% in every neighbourhood; and that distance from every residence to the nearest public green space not exceed 300 metres (Konijnendijk, 2023).

Because trees grow slowly, significant areas of urban vegetated landscapes are a legacy of past land-use decisions (Boone et al., 2010; Roman et al., 2018). Young trees do not have the same canopy characteristics or visual effect on landscapes as mature trees. Chi et al. (2022) showed that exposure to fewer larger trees has a greater impact on cardiovascular health and mood disorders than exposure to a higher number of smaller trees.

Exposure to green and blue spaces is positively associated with various mental and physical health indicators, including reduced stress, healthier cortisol levels, lower risk of psychological distress and higher perceived general health (Douglas et al., 2017; van den Berg, A. E. et al., 2010). Exposure to residential area vegetation is also positively associated with improved cognitive function and various aspects of child development (Jarvis et al., 2022).

Another benefit that is associated with visual amenity services is the increase in the value of properties located near green and blue spaces, which can be estimated using a hedonic price model. Research shows that desirable environmental attributes have a positive effect on house prices (Czembrowski & Kronenberg, 2016; Luttik, 2000). However, higher housing prices near urban green spaces may lead to the displacement of households with lower income (Quinton et al., 2022), precluding them from accessing the benefits associated with visual amenity services (Section 6).

Following the SEEA EA, “amenity related services arise in the context of benefits people obtain from living or working in a specific location.” (United Nations et al., 2021, para. 6.58). In other words, the use of visual amenity services is dependent on the location of and demand for residences, schools, offices and other frequently visited buildings near green and blue spaces, and whether the design of buildings allows for the visual enjoyment of nearby vegetation. Focusing on potential beneficiaries—those who reside and work next to green and blue spaces—is an indirect but simple way of quantitatively measuring visual amenity services.

Proposed metrics

- Number of residential and office buildings located near green and blue spaces (using vegetation characteristics such as vegetation cover, tree canopy cover or number of trees) (count)
- Population residing near green and blue spaces (using vegetation characteristics) (count and proportion)
- Premium on property values or rental values arising from proximity to green and blue spaces (dollars)

5.2 Ecosystem services supplied by immediate upstream watersheds

Ecosystem services used by people who live or work in urban areas may be flowing from surrounding ecosystems. Ecosystems in the immediate upstream watersheds of urban areas supply services that help address important challenges linked to water management and are included within the scope of this framework as part of the extended accounting area (Section 2.2).

In practice, the extended accounting area may be delineated using the work unit layer of NRCan’s National Hydrographic Network (NHN) (NRCan, 2025). These units are the smallest geographical units in the NHN (Statistics Canada, 2017). Upstream work units are identified using the direction of water flow in the NHN[13] (Map 3).

5.2.1 Water supply

Water supply services are the contribution of ecosystems to the provision of good-quality water. These services result from the combined contribution of ecosystems to the maintenance of base flows and water purification (United Nations et al., 2021). They act as intermediate services in provisioning biomass such as fish and shellfish harvests from urban blue spaces, and recreational activity opportunities such as swimming.

13. The Great Lakes and the St. Lawrence River are not part of the NHN work units, so an alternative method must be identified for several large urban areas in proximity to this hydrographic complex.

Water is supplied from upstream inland water resources, made up of surface water (e.g., lakes, rivers, glaciers, reservoirs), groundwater and water present in the soil of terrestrial ecosystems. Water resources are in constant motion and are replenished by precipitation and inflows from other locations, while being drawn down by evapotranspiration and outflows (Portela et al., 2019).

Base flow maintenance—or the storage and gradual release of water by ecosystems—sustains water availability over time, particularly during periods of drought (United Nations et al., 2021; Strange et al., 1999). For instance, riparian areas, found along water bodies or water courses, act like sponges, helping attenuate the impacts of dry conditions. Water purification is supplied by natural and semi-natural ecosystems, particularly wetlands and riparian areas, which filter pollutants and thus improve water quality and reduce requirements for water treatment. Green stormwater management technologies (e.g., bioswales) also contribute by directing stormwater runoff to permeable surfaces where nutrients and other pollutants are filtered before runoff reaches downstream water bodies (USDA Forest Service, 2020).

Water supply services depend on a complex interplay of ecological and societal factors. In upstream watersheds, water quantity is impacted at different times of the year by hydrogeological characteristics, including topography, soil type and saturation level, coupled with climate characteristics like temperature and precipitation (Milly et al., 2005; Oki & Kanae, 2006). The biomass, type and age of vegetation influence water storage and water quality through evapotranspiration and water infiltration (Smith et al., 2017).

In upstream watersheds and cities, practices such as stormwater management, flood and erosion management, and reforestation, as well as conservation and restoration of wetlands and riparian areas, enhance ecosystem functions and contribute to the maintenance of base flows and water purification (Lowrance et al., 2002). Within the urban area, water quality is also affected by pollution loading; pollutant transformation; and aspects such as water flow, temperature and vegetation (Konapala et al., 2020).

Water use is affected by factors such as per capita water consumption, population, and industrial and agricultural activities (Noiva et al., 2016). Regulations that govern quality standards and water rights, pricing mechanisms (Vander Ploeg, 2011), and advances in water treatment (Sun & Chu, 2021), as well as other social and cultural factors, are all determinants of water use.

The water supplied by ecosystems is treated by drinking water plants and distributed to households and other sectors. People who live or work in urban areas benefit from safe water for drinking, cooking, hygiene and gardening. Natural water sources reduce the need for other forms of water storage, such as artificial water storage systems (Boholm & Prutzer, 2017). Sectors like agriculture, manufacturing, construction and mining also need a reliable supply of clean water for their operations.

Water supply is measured by the volume of water abstracted per year. The Biennial Drinking Water Plants Survey (Statistics Canada, 2022e) and the Water Survey of Canada (Statistics Canada, 2019) provide data on the quantity of drinking water used by sector and water yield for selected drainage regions in southern Canada. Water yield, or the amount of freshwater flowing via rivers and streams in a month or year, can be used as a proxy to measure potential water supply. Estimating the proposed metrics for large urban areas or immediate upstream watersheds will require further research and development.

Proposed metrics

- Total volume of water abstracted for use by households and industry, total and per capita (cubic metres per year and cubic metres per person per year)
- Amount of drinking water used by residential and non-residential sectors (cubic metres per year)
- Proxy: Annual water yield (cubic kilometres)

5.2.2 Water flow regulation to mitigate extreme water-related events

Water flow regulation services to mitigate extreme water-related events are supplied by vegetation and natural structures acting as buffers or barriers to prevent or reduce the impacts of floods and extreme rainfall on communities (United Nations et al., 2021). River flood mitigation and peak flow mitigation work together to regulate water flow. Coastal protection services are distinct services that are not covered in this framework, while droughts are treated in the context of water supply services (Section 5.2.1).

Urban green and blue spaces and vegetated and aquatic ecosystems in the upstream watersheds—particularly riparian areas, wetlands and water bodies—intercept, absorb and hold water, reducing runoff during extreme events and decreasing the frequency and intensity of floods (Nowak & Dwyer, 2007; Crossman et al., 2019; Tabacchi et al., 2000). Green roofs, bioswales, permeable pavement and other green stormwater management technologies also contribute to water flow regulation (Stefanakis, 2019; USDA Forest Service, 2020).

Water flow regulation services provided by urban areas and upstream watersheds are influenced—through impacts on runoff, water infiltration and storage—by vegetation type, cover and density; vegetated patch size; and soil properties such as type, texture, porosity and organic matter content (Heris et al., 2021; Smith et al., 2017). For example, wildfires in British Columbia in 2021 contributed to severe flooding later that year because of the loss of vegetation and soil cover, and soil degradation (Rhoades et al., 2019; Williams et al., 2019).

Trees in urban areas intercept rainfall by capturing it on their leaves, leading to increased evaporation of water and a reduction in the amount of water that runs off the soil surface. Rainfall interception depends on temperature, humidity, wind speed, and rainfall intensity and duration, as well as on tree species, canopy cover and LAI (Keim et al., 2006; USDA Forest Service, 2020; Heris et al., 2021). On an annual scale, deciduous trees capture around 20% of the rainfall landing on their canopy, while conifers retain nearly 30% (Kuehler et al., 2017; USDA Forest Service, 2020). Asadian and Weiler (2009) showed that urban trees, which are typically more distanced from each other and have a larger canopy, can intercept twice as much water as forest trees.

The use of water flow regulation services to mitigate extreme water-related events is determined by flood risk, the spatial distribution of people and infrastructure with respect to the risk, and the feasibility and cost associated with mitigating extreme events using produced assets (Crossman et al., 2019). Water flow regulation services reduce protection costs and prevent damage. For example, they can lower stormwater treatment costs and protect against erosion (Heris et al., 2021; Smith et al., 2017). Households that face a lower risk of flooding are also less at risk from stress, anxiety, and long-term impacts associated with flood events such as depression and post-traumatic stress disorder (Stanke et al., 2012).

Measuring water flow regulation involves estimating the area or number of people with a reduced risk of being impacted by flood or extreme rainfall. This can be done by using watershed-based hydrological models to quantify the reduction of peak flow. These models integrate spatial variables such as land use and land cover, topography, soil properties, precipitation, and hydrological data.

The i-Tree Hydro modelling tool can be used to estimate the reduction in peak flow rates during heavy rainfall events by modelling stormwater retention, rainwater interception and infiltration from urban green assets (Nowak, 2024). By contrast, the InVEST model (Integrated Valuation of Ecosystem Services and Tradeoffs) calculates the proportion of stormwater retained at the pixel level to estimate urban stormwater mitigation (Natural Capital Project, 2025). This model estimates the reduction in runoff over a year, differing from iTree's emphasis on short-term heavy rainfall events. These models are limited by the quality of input data and often do not represent site conditions accurately.

Proposed metrics

- Stormwater retention volume (cubic metres per year)
- Stormwater retention to total water volume during peak flows (percentage)
- Rainfall interception by urban trees to total water volume during peak flows (percentage)
- Number of people benefiting from reduced flood risk (count)

6 Environmental inequality

The framework's focus on population well-being raises considerations related to fairness and inclusion and the need for reliable disaggregated data to inform decision making on matters pertaining to public health, environmental quality and adaptation to climate change. As part of the Disaggregated Data Action Plan, Statistics Canada is committed to improving statistics on Indigenous peoples, women, racialized groups and persons with disabilities (Statistics Canada, 2024b). Other relevant population groups to consider include immigrants, people with low income, children, youth and seniors.

Decades of research have demonstrated that the harms and benefits derived from the environment are not distributed fairly across society (Mohai et al., 2009). This phenomenon is captured by the concept of environmental inequality, where population groups defined by characteristics such as income, gender or ethnicity are disproportionately impacted by environmental issues. Environmental inequality is the result of an ongoing process where human activity, market dynamics, past and present urban planning decisions, the scarcity of available land in urban areas, and existing socioeconomic inequalities interact in complex ways (Ernstson, 2013; Pellow, 2000).

Ecosystem services can help reduce environmental inequalities by mitigating the impacts of environmental hazards on communities or, conversely, contribute to inequalities by disproportionately benefiting certain groups. In Canada, a national statistical analysis of exposure to residential area vegetation across CMAs found that the mean NDVI within 500 metres of home was lower for renters, young adults, people with lower incomes, immigrants (especially recent immigrants) and some racialized groups (especially those of Filipino ancestry) (Pinault et al., 2021).

People can be exposed equally to environmental hazards, but not all people are equally vulnerable to them. Vulnerability represents how people can be impacted differently by a given issue and why they may derive greater benefits from ecosystem services (IPCC, 2023b). It stems from limitations (e.g., age, chronic illness, low income) that prevent people from anticipating, adapting to or responding to dangerous events (Cardona et al., 2012). For instance, an individual residing in an area affected by the urban heat island effect who is unable to afford air conditioning or access a public space with air conditioning would be considered more vulnerable to heat waves.

While the SEEA EA's general framework does not cover the measurement of environmental inequality, relevant metrics can be developed as part of urban thematic accounts. To observe environmental inequalities within cities, fine-scale environmental and population data are mapped to small spatial observation units. Statistics Canada's CT and DA would be well suited for this application because of their small size, their relative stability over time and the availability of many variables at these levels from the Census of Population (Statistics Canada, 2023b).

To measure and document environmental inequality, disaggregation of ecosystem condition or service metrics by various population characteristics and small geographic areas will be considered where feasible, depending on relevance and the demand for this information.

The Canadian Census Health and Environment Cohorts (CanCHECs) provide a rich national data resource that can be used to measure and examine the effects of exposure to environmental factors on human health across socioeconomic and ethnocultural dimensions for different periods and locations (Statistics Canada, n.d.-c). The datasets combine long-form census questionnaire respondents (and National Household Survey respondents) with administrative health data (e.g., mortality, cancer, hospitalizations, ambulatory care and mental health) and annual mailing address postal codes. In the future, environmental data produced for the ecosystem accounts for large urban areas could be linked to the CanCHECs based on postal codes to examine the relationship between ecosystem services supplied in urban areas and health outcomes by population characteristics.

Selected examples of metrics disaggregated by population group

- Population living within 400 metres of public green and blue spaces by population group (count and proportion)
- Population with access to a yard or community garden by population group (count and proportion)
- Population living in a flood zone by population group (count and proportion)

7 Conclusion

The ecosystem accounts for large urban areas in Canada will help communities, people and policy makers across the country better understand the changing ecosystem conditions and benefits of urban green and blue spaces or nearby ecosystems. Focusing on population well-being, this paper has laid out an ecosystem accounting framework for large urban areas in Canada, proposing foundational concepts and definitions, as well as characteristics and metrics to represent and measure the condition and services of urban ecosystems. Ecosystem accounts for large urban areas will be developed incrementally as knowledge and technology improve, with priority given to the variables that are the most relevant and for which data can be easily integrated.

At the national level, the data will help monitor progress toward international targets, such as target 12 of the KMGBF to “enhance green spaces and urban planning for human well-being and biodiversity” (Convention on Biological Diversity, n.d.). The ecosystem accounts provide a tool to reveal the consequences of medium- to large-scale trends, such as the impact of tree diseases or wildfires on ecosystem services, and the effects of planning efforts and investments in the context of a changing climate (Heris et al., 2021). Comparing results across urban areas could help understand the influence of urban size and form, climate conditions or development policies on ecosystem services.

The national urban accounts will emphasize consistency across locations, which allows for benchmarking and is an advantage for analysis and decision making. Synergies between this framework and efforts by local governments to identify and report on natural assets could have mutually beneficial applications.

Accounts data will support work to measure the mental and physical health benefits of nature in cities for different population groups. Given the small-scale heterogeneity in population characteristics and ecosystem conditions within cities, disaggregation by intra-urban geography is important for the meaningful assessment of environmental inequality and will be pursued wherever data are available.

Glossary

Abiotic: Non-living elements of the environment.

Adaptation: Adjustment to actual or expected climate and its effects on the environment to mitigate harm or exploit beneficial opportunities (IPCC, 2023b).

Albedo: The proportion of sunlight that a surface or object reflects.

Artificial surfaces and associated areas: Based on the Land Cover Classification System (Di Gregorio and Jansen, 2000). This land cover class refers to any type of area with a predominant artificial surface resulting from human activities. Artificial surfaces include built-up areas (cities, towns, transportation infrastructure) and non-built-up areas (open mines, quarries, landfills). This class also includes any urban or related feature such as urban parks, parkland and lawns.

See “Built-up area.”

Biomass: The mass of living organisms.

Bioswale: Vegetated channel designed to convey runoff and maximize water infiltration and treatment (Canadian Council of Ministers of the Environment, 2021).

Biotic: Living elements of the environment.

Built-up area: As a land cover class, the substitution of the original natural or semi-natural cover or water surface by an artificial, often impervious and usually long-duration cover. Built-up areas include linear structures (i.e., roads, railways, communication lines and pipelines) and non-linear areas (industrial and other or urban) (Di Gregorio and Jansen, 2000).

From a land use classification perspective, built-up area refers to land affected or adapted by humans for the pursuit of human activities. This includes certain types of open land and vegetated area (non-built-up land) that are closely related to these activities, such as landfills, vacant lots, city parks and gardens. Built-up area includes the following land use subclasses: mining and quarrying; construction; manufacturing; technical infrastructure; transport and storage; commercial, financial and public services; recreational facilities; and residential (United Nations et al., 2014).

See “Land cover” and “Land use.”

Contiguously settled area (CSA): Representation of the physical footprint of settled areas on the landscape. CSA boundaries are delineated based on land cover data derived from Earth observation. CSAs include “contiguous development outside the urban core while excluding natural and semi-natural land covers on the periphery of the main settled area” (Allen and Henry, 2023).

Crowdsourced science: The participation of the public in scientific research, also referred to as citizen science.

Ecosystem: “[…A] dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit” (Convention on Biological Diversity, 2006).

Ecosystem accounts: “[…A] spatially based, integrated statistical framework for organizing biophysical information on ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets and linking this information to measures of economic and human activity” (United Nations et al., 2021, p. 3).

Ecosystem condition: “[…The] quality of an ecosystem measured in terms of its abiotic and biotic characteristics” (United Nations et al., 2021, p. 31).

Ecosystem services: “[…The] contributions of ecosystems to the benefits that are used in economic and other human activity” (United Nations et al., 2021, p. 31). “Final ecosystem services are used by the economy and people (economic units). Intermediate services are used by other ecosystems and contribute to the supply of final ecosystem services” (Statistics Canada, 2023a, Ecosystem services flow accounts).

Ecozone: “Ecozones represent areas of the earth’s surface representative of large and very generalized ecological units […]” (Statistics Canada, 2021, Table 1: Ecological framework levels).

Environmental inequality: The situation where population groups defined by characteristics such as income, gender or ethnicity are disproportionately impacted by environmental issues (Ernstson, 2013; Mohai et al., 2009; Pellow, 2000).

Evapotranspiration: The combined processes of water evaporation from soil surfaces and transpiration from plants into the atmosphere.

Food security: The situation “when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (IPCC, 2023b, p. 2909).

Fraction of absorbed photosynthetically active radiation (FAPAR): The fraction of photosynthetically active radiation that is absorbed by vegetation on the ground.

Fraction of vegetation cover (FVC): The fraction of ground covered by all green vegetation.

Generalist species: Species able to use different resources and survive in a variety of environmental conditions (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], n.d.).

Green engineered elements: Also known as green stormwater management systems. Human-made structures usually made from a combination of artificial materials and natural elements (e.g., vegetation and soil). Green engineered elements are designed to mimic the functions of nature and, as such, are used for managing stormwater runoff. They also provide other benefits associated with green and blue spaces. Examples include green roofs and walls, permeable pavements, bioswales, rain gardens, and retention ponds (Canadian Council of Ministers of the Environment, 2021).

Hazard: "The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources" (IPCC, 2023b, p. 2911).

Heat wave: An extended period of unusually hot weather.

Impacts: The effects of climate-related and environmental hazards on people, the built environment and ecosystems (including ecosystem services) (IPCC, 2023b).

Land cover: The observed biophysical coverage of the Earth's surface. Land cover is categorized into classes (e.g., natural and semi-natural vegetated areas, cultivated and managed terrestrial areas, artificial surfaces and related areas) (Di Gregorio and Jansen, 2000; IPCC, 2023b).

Land use: The activities "applied to a parcel of land." Land use is categorized into classes (IPCC, 2023b, p. 2914).

Large urban area: The area delineated by contiguously settled area boundaries for large urban population centres.

See "Contiguously settled area."

Leaf area index (LAI): An indicator quantifying the total one-sided leaf surface area per ground surface area.

Metric: A general method of measurement for a variable.

Normalized Difference Vegetation Index (NDVI): An indicator of vegetation presence and quantity calculated based on satellite spectrometric data.

Particulate matter: A microscopic mixture of solid particles (dust, dirt, soot or smoke) and liquid droplets of natural or anthropogenic sources (IPBES, n.d.).

Peri-urban area: The transition area between urban and rural areas. It is characterized by intense interactions between urban and rural economies, activities, households and lifestyles (IPCC, 2023b).

Permeable surfaces: Also known as porous or pervious surfaces. They allow water to percolate into the soil to filter out pollutants and recharge the water table. Impermeable or impervious surfaces are solid surfaces that do not allow water to penetrate, forcing it to run off (Pineo, 2024).

Proxy: An indirect representation.

Riparian area: Transitional area between water bodies and land.

Rural area: The area often defined in opposition to urban areas because they are both part of a continuum that describes various aspects of human settlements. These aspects include, among others, the size and density of the population (IPCC, 2023b). According to the Census of Population geography, rural areas are defined as including all territory outside of population centre boundaries. From an ecosystem perspective, rural areas can include patches of urban and industrial ecosystems.

Serviceshed: The area where an ecosystem service is supplied to a specific group of people (Zhang et al., 2025).

Settlement: A place of concentrated human habitation and related infrastructure. Settlements vary in size from small rural villages to large cities (IPCC, 2023b).

Specialist species: Species that can survive in only a specific range of environmental conditions and use only a few different resources (IPBES, n.d.).

Species abundance: The population size of a particular species in a given area (IPBES, n.d.).

Species diversity: The number of species (species richness) and their relative abundance in a given area (Baillie & Upham, 2012).

Species richness: The number of species in a given area (IPBES, n.d.).

Topography: The natural and artificial features of the Earth's surface.

Urban and industrial ecosystems: An ecosystem functional group under the intensive land-use biome of the International Union for Conservation of Nature Global Ecosystem Typology. Urban and industrial ecosystems are structurally complex areas characterized by a patchwork of buildings, roads and other artificial surfaces, but also bare ground, vegetation and water features of different sizes and shapes (such as parks, gardens, street trees, rivers and riparian areas). Urban and industrial ecosystems often have simplified biotic communities and altered ecosystem functions, and they are highly dependent on external flows of water, energy and nutrients (Keith et al., 2020).

Urban green and blue spaces: Areas of vegetation and inland and coastal waters in urban areas. Urban green and blue spaces provide important ecosystem services and are essential assets of urban ecosystems.

Urban heat island: An area experiencing higher temperatures because of the configuration and properties of the built environment, including the materials used in buildings and streets, the reduced presence of vegetation and water, and heat emissions generated by human activities (IPCC, 2023b).

Vulnerability: The propensity to be negatively impacted by a given issue (IPCC, 2023b). Vulnerability stems from limitations linked to age, chronic illness, income, disability or other aspects of a person's situation that prevent them from anticipating, adapting to or responding to dangerous events (Cardona et al., 2012).

Well-being: A multidimensional state of being that encompasses people's material and living conditions, physical and mental health, connections and engagement with the local community, and subjective perception of their overall quality of life (OECD, 2020).

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