CEREALS CANADA

Environmental Sustainability of Canadian Wheat

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Executive Summary

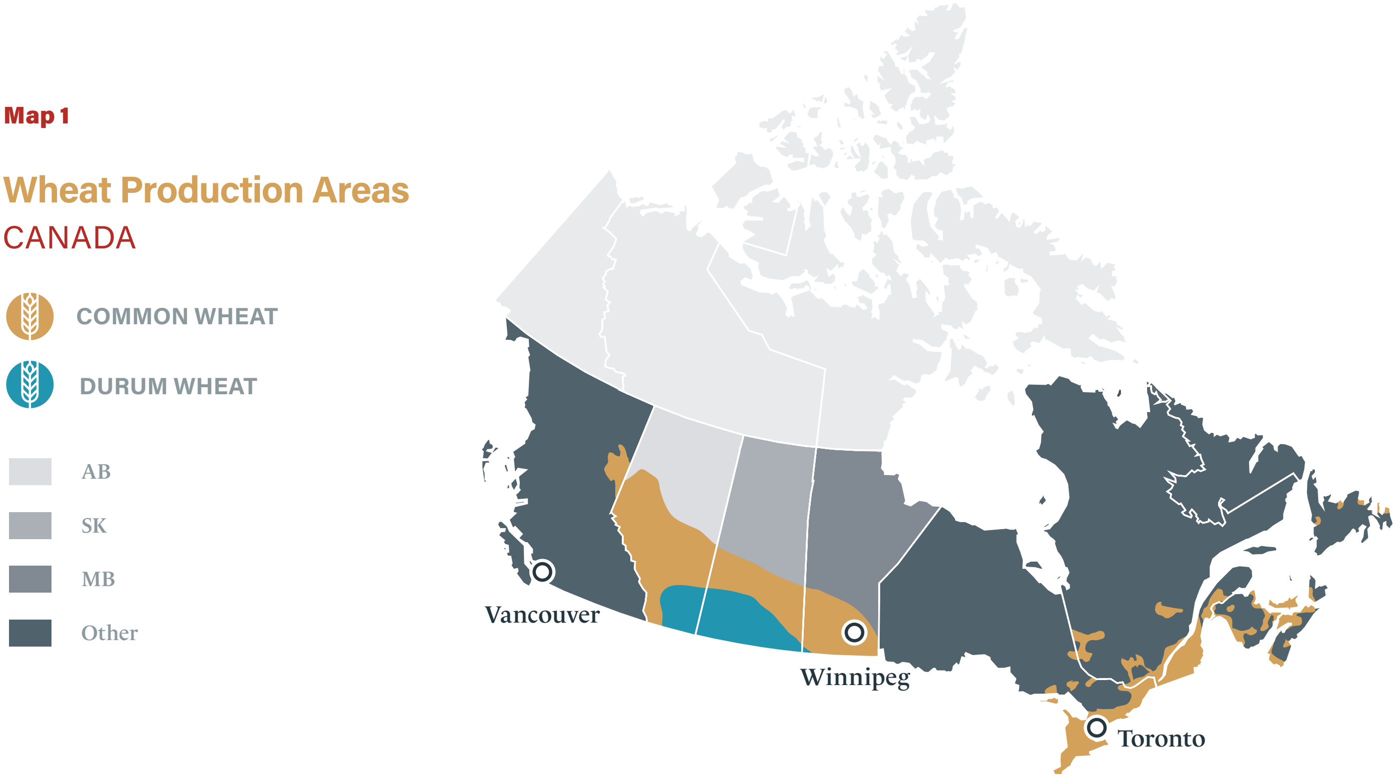
Wheat is a cornerstone of global food security and increases in production will be necessary to feed the expanding global population (Hatfield and Beres, 2019). Wheat is the largest field crop grown in Canada, where is it used domestically as well as exported to over 80 countries (Cereals Canada, 2024).

In Canada, non-durum wheat is seeded to approximately 19.6 million acres, with a 5-year average production of over 27 million tonnes annually (Statistics Canada, 2025b). In 2023, Canada exported nearly $9.5 billion worth of non-durum wheat, making it the third largest exporter of non-durum wheat in the world (Statistics Canada, 2025a; LSEG, 2025; Zen Innovations, 2025). Of the nearly 35 million tonnes of wheat produced in Canada in 2024, 90% was spring wheat grown in the prairies, and 9% was winter wheat, which is primarily cultivated in the province of Ontario (Statistics Canada, 2025b). In Canada, the predominant classes of spring wheat are Canada Western Red Spring (CWRS), with an average seeded area of 15.2 million acres, and Canada Prairie Spring Red (CPSR), with an average seeded area of 1.3 million acres. On average, winter wheat is planted on 1.4 million acres (Statistics Canada, 2025b).

This report only focuses on spring and winter wheat which will be referred to as wheat in the report. For more information on durum wheat, please see The Sustainability of Canadian Durum Wheat Production (Cereals Canada, 2025).

Map 1

Wheat Production Areas
CANADA



Executive Summary

Agricultural production of adequate quantities of high-quality food will be one of the most important challenges for humanity in the next century. The concept of sustainability is one of the forefront concepts in discussions of the challenges facing agriculture, given the pressing need to increase food production in a sustainable way. In this situation of growing awareness, increasing emphasis on sustainable production of agricultural products has led to a demand for measurements of environmental sustainability. This report was prepared by Cereals Canada to respond to these demands, with the purpose of evaluating the sustainability of the production of a key Canadian agricultural commodity, wheat.

In this report, Cereals Canada compares the sustainability of Canadian wheat production systems to two other major wheat production systems, the United States and Australia, using six sustainability indicators: (1) carbon footprint of wheat production, (2) soil organic carbon (SOC) sequestration, (3) fertilizer use and efficiency, (4) irrigation water use, (5) pesticide use, and (6) soil erosion.

The indicators were developed using quantitative measurements using robust data to evaluate the environmental sustainability of Canadian wheat production. For each indicator, wheat-specific data was used when possible, however, when data availability precluded this, Cereals Canada has indicated when cropland-specific data was used.

Based on the analysis, the following conclusions can be made about the sustainability of Canadian wheat production:

1. The carbon footprint of wheat per tonne of grain in Canada is substantially lower compared to the carbon footprint of wheat produced in the United States or Australia when accounting for soil organic carbon (SOC) sequestration.
2. Canadian agriculture soil is a net sink for carbon dioxide (CO_2) at a rate of 14.2 million tonnes per year (5-year average). Canada grows high quality, high protein wheat. Canadian farmers produce the highest tonnes of protein per acre of wheat grown. The result of this is a very low carbon footprint per kilogram of protein produced.
3. Application rates of nitrogen (N) fertilizer for Canadian wheat production are tailored to grow high protein wheat, balancing food production and environmental considerations.
4. In Canada, irrigation pressures are minimal as the majority of wheat is grown under dryland conditions. Compared to the United States and Australia, Canada uses less irrigation water to grow wheat.
5. Pesticides are strictly regulated in Canada to ensure their safety for human health and the environment. Pesticides are a tool used for wheat production in Canada, the United States, and Australia. Glyphosate is an herbicide approved for use in all three countries and is subject to comparable label application rates for analogous products in cereal production systems.
6. Conservation management practices adopted by Canadian wheat producers such as conservation or no-till management, diversification of crop rotations, cover cropping, and the establishment of vegetative buffer strips and grassed waterways facilitate soil organic carbon (SOC) sequestration and mitigate soil erosion, such that soil erosion in Canada has declined substantially and over 80% of cropland in Canada is classified as "very low risk" (soil erosion rates less than 2.5 tonnes per acre per year).

Executive Summary

Canadian farmers have responded to demands for sustainable food production by adopting new technologies and conservation management practices that have reduced the environmental impact of Canadian wheat production. Investment by the Canadian government and the private sector into research, innovation, and incentivization are necessary to build upon the sustainability gains already achieved by wheat producers and the Canadian agricultural sector as a whole.

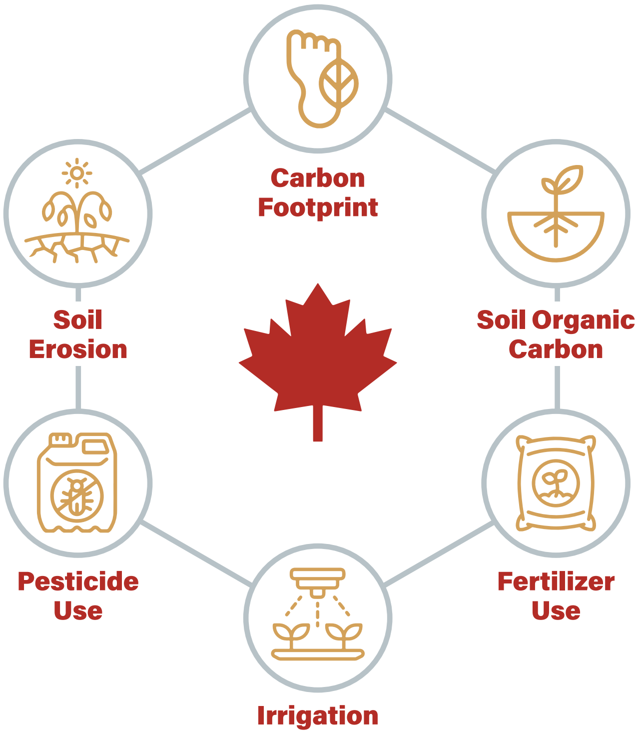
Assessing the Sustainability of Canadian Wheat

The benefits from agriculture are immense; agriculture provides quality food, fuel, and fibre. Continuing to meet the demand for agricultural products will be an important challenge for humanity in the next century (Lampridi et al., 2019). Global demand for major grains is expected to increase 70%, due to greater pressure from a global population expected to reach 9.7 billion by 2050 (Gan et al., 2014; Tilman et al., 2011; Beres et al., 2020). Sustainable agricultural intensification is necessary to maintain global food security and nutritional needs (Lampridi et al., 2019; Ajibade et al., 2023). Increasing emphasis on sustainable production of agricultural products has led to a demand for measurements of sustainability. Environmental sustainability for agriculture means managing our natural resources to meet society's food, fuel, fibre, and feed needs without compromising the ability of future generations to meet their needs (Lampridi et al., 2019).

Wheat is a cornerstone of global food security and increases in production will be necessary to feed the expanding global population (Hatfield and Beres, 2019). Wheat is the largest field crop grown in Canada, where is it used domestically as well as exported to over 80 countries (Cereals Canada, 2024). In Canada, non-durum wheat is seeded to approximately 19.6 million acres, with a 5-year average production of over 27 million tonnes annually (Statistics Canada, 2025b). In 2023, Canada exported nearly $9.5 billion worth of non-durum wheat, making it the third largest exporter of non-durum wheat in the world (Statistics Canada, 2025a; LSEG, 2025; Zen Innovations, 2025).

To evaluate the environmental sustainability of Canadian wheat production, Cereals Canada has developed a set of six environmental sustainability indicators: carbon footprint, soil organic carbon sequestration, fertilizer use and efficiency, irrigation water use, pesticide use, and soil erosion (Figure 1). The indicators were developed to evaluate the environmental sustainability of Canadian wheat production and relate to environmental challenges that stakeholders in the agriculture sector seek to address (Latruffe et al., 2016). The selected indicators rely on robust data, recognizing that their development is subject to data availability. For each indicator, wheat-specific data were used when possible, however, when data availability precluded this, Cereals Canada has indicated when general cropland level data were used. The selected indicators were then applied to two other major wheat producing regions, the United States and Australia, to comparatively evaluate the sustainability of Canadian wheat production. The direct comparison of environmental indicators between nations is challenging because of regional differences in environmental conditions, economic activity, and the availability of data across countries. Therefore, these indicators do not act as direct comparisons but instead should be used as a guide to understand the sustainability strengths of Canadian wheat production in a broader context.

Figure 1 Six indicators to evaluate the sustainability of Canadian wheat production relative to production of wheat in the United States and Australia.

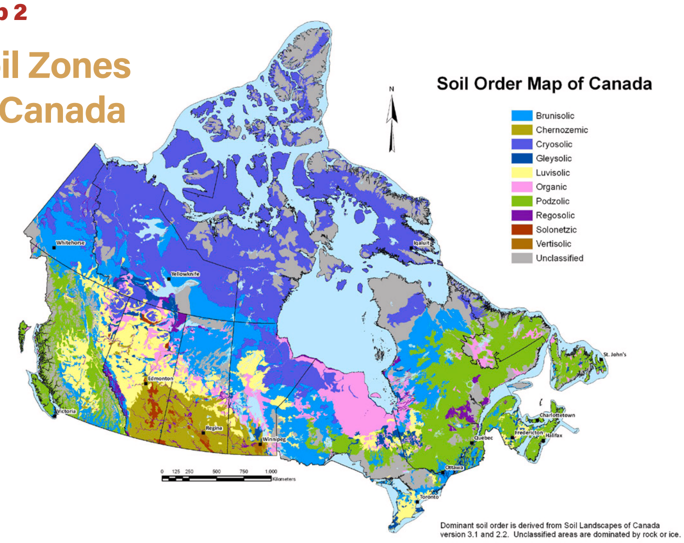


In Canada, wheat is grown from coast to coast. The majority of spring wheat is grown in the prairie provinces of Alberta, Saskatchewan, and Manitoba, whereas Ontario is the largest producer of winter wheat.

In general, the wheat growing region of the prairies is characterized by its aridity (McGinn, 2010). There are five major soil zones in Canadian prairies (Brown, Dark-brown, Black, Grey and Dark Grey Chernozems) with a general precipitation gradient along these soil types; the Brown soil zone is the most arid and the Black/Grey zones are wetter and cooler, resulting in higher soil organic matter (2-5% vs. 5-10%) (Awada et al. 2021). In Ontario, winter wheat production primarily occurs in a mild ecozone with much greater precipitation on clayey glacio-lacustrine plains dominated by Humic Gleysols and Gray-Brown Luvisols (Saurette et al., 2021).

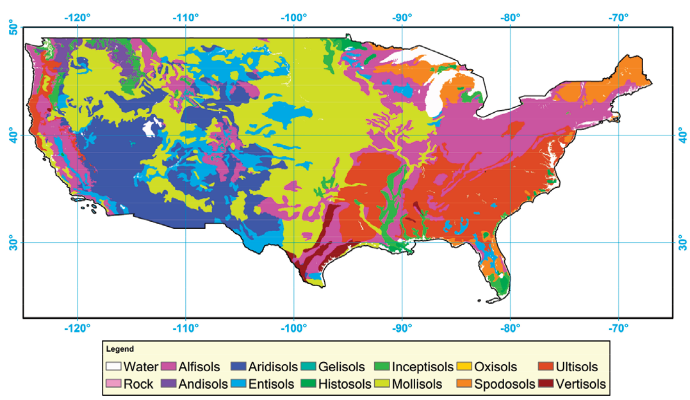
Map 2

Soil Zones of Canada



Map 3

Soil Zones of the United States

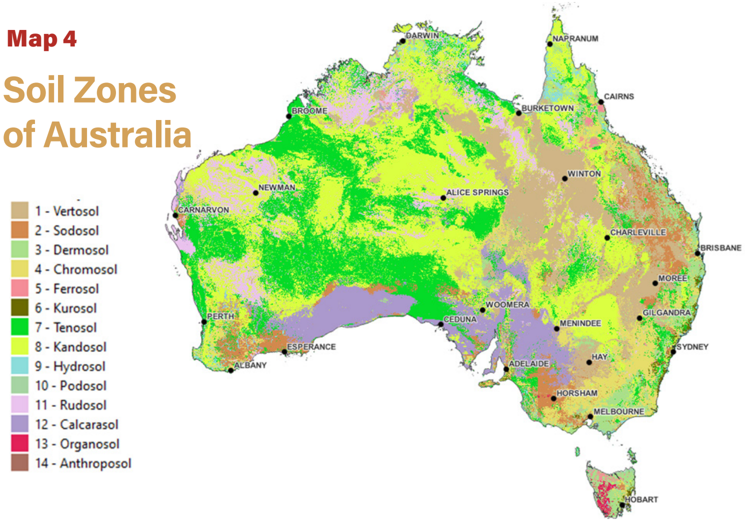


Wheat is grown throughout the continental United States, but primarily in the Northern and Southern Plains. In the Northern Plains region, the climate is similar to the Canadian prairies, with short hot summers and low precipitation, and topsoil with high organic matter (2-8%) (Padbury et al., 2002). The Southern Plains generally have warmer summers, milder winters, and a longer growing season with more annual precipitation, however, aridity increases from east to west resulting in deeper soils higher in organic matter in the east and shallower, lower organic matter soils in the west (EPA, 2016).

In Australia, wheat is grown from southern Queensland to Western Australia and therefore a wide range of soil types. Black, grey, and brown vertosolic soils with high fertility dominate the crop production regions in the east, whereas low fertility sandy soils dominate the agricultural zones of the southwest (organic matter 0.4 - 4%) (Government of Western Australia, 2022). Similarly, the climate ranges from semiarid to subtropical in Queensland to Mediterranean in Western Australia (Soil Quality, 2024).

Map 4

Soil Zones of Australia



Wheat Types Grown in Canada, United States, and Australia

There are ten wheat classes grown in Western Canada and seven in Eastern Canada. Canadian wheat varieties are grouped into classes by their functional characteristics and categorized as western Canadian or eastern Canadian to meet distinct quality attributes for processors and end-users. Within each class of wheat are multiple varieties with specific qualities and characteristics (Cereals Canada, 2024).

In Canada, the predominant classes of spring wheat are Canada Western Red Spring (CWRS), with an average seeded area of 15.2 million acres, and Canada Prairie Spring Red (CPSR), with an average seeded area of 1.3 million acres. On average, winter wheat is planted on 1.4 million acres (Statistics Canada, 2025b).

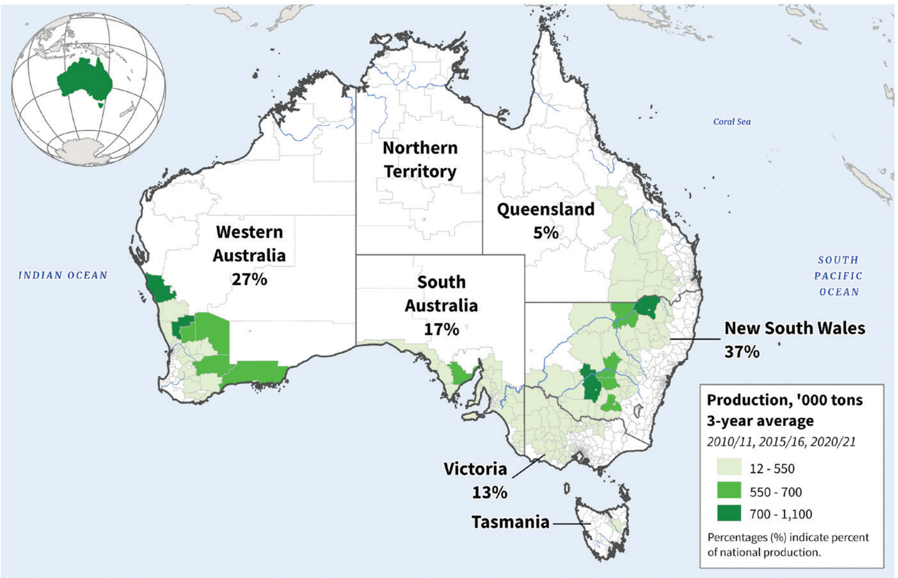
Of the nearly 35 million tonnes of wheat produced in Canada in 2024, 90% was spring wheat grown in the prairies, and 9% was winter wheat, which is primarily cultivated in the province of Ontario (Statistics Canada, 2025b).

Not included in this report is Canada Western Amber Durum (CWAD) which is seeded to approximately 6 million acres each year. For more information on durum wheat, please see The Sustainability of Canadian Durum Wheat Production (Cereals Canada, 2025).

Australian wheat varieties are classified into 10 classes to meet distinct quality attributes for processors and end-users. The most common wheat classes include Australian Premium White (30-40%), Australian Standard White (20-25%), Australian Hard (15-20%), Australian Prime Hard (5-10%), and Australian Premium White Noodle (5-10%) (AEGIC, 2022). Wheat is the major winter crop grown in Australia.

Map 5

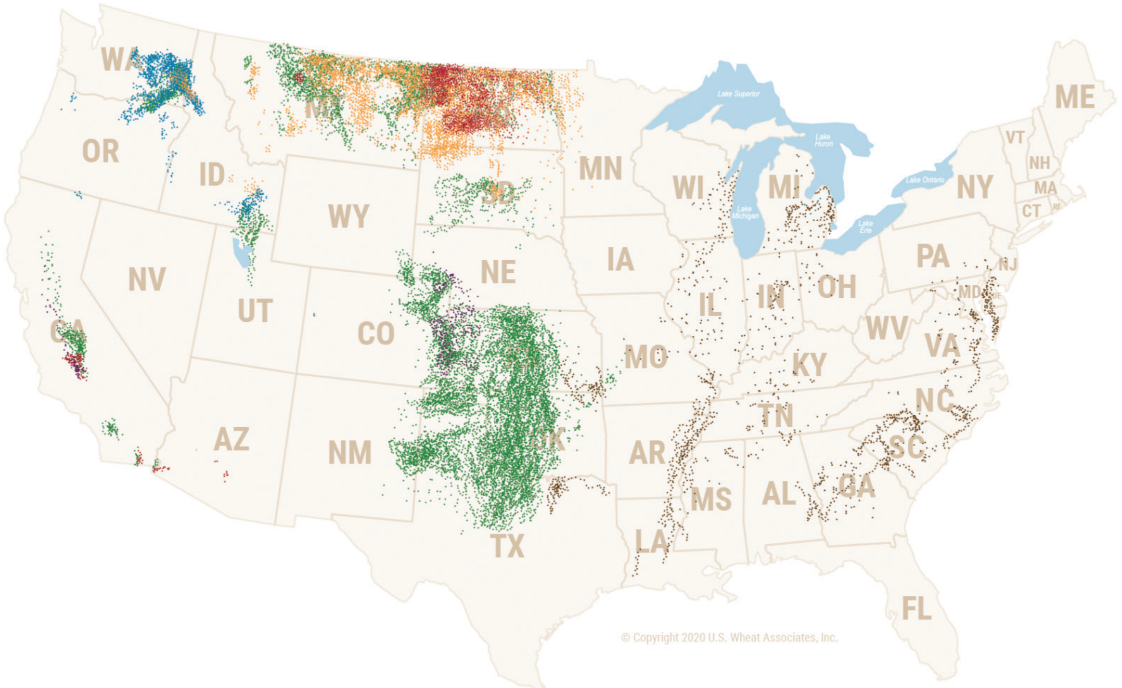
Wheat Production Australia



The main producing states are Western Australia, New South Wales, South Australia, Victoria, and Queensland (Australian Government Department of Agriculture, Fisheries and Forestry, 2023).

Map 6

Wheat Production the United States



Hard Red Winter (HRW) · Soft Red Winter (SRW) · Hard White (HW)

Hard Red Spring (HRS) · Soft White (SW) · Durum

The United States has three primary varieties of wheat: winter wheat, spring wheat, and durum wheat. Winter wheat and spring wheat can be disaggregated into four major classes: Hard Red Winter (~40%), Hard Red Spring (~25%), Soft Red Winter (15-20%), and white (12-17%). Winter varieties are more often grown in the Southern states, whereas spring varieties are commonly grown on the Northern Great Plains (USDA, 2023).

The Carbon Footprint of Canadian Wheat Production

Terminology:

Carbon footprint is the sum of greenhouse gas (GHG) emissions caused directly and indirectly by the production of a product, reported as kg of carbon dioxide equivalents (CO_2eq) per tonne of grain production (kg CO_2eq per tonne).

The CO_2eq is used to compare the emissions from three major greenhouse gases (carbon dioxide [CO_2], nitrous oxide [N_2O], and methane [CH_4]) on the basis of their global-warming potential by converting N_2O and CH_4 to the equivalent amount of CO_2 (Pandey and Agrawal, 2014). Importantly, carbon footprint estimates can vary substantially depending on the individual methodologies, therefore, only comparable carbon footprint calculations are considered in the estimates. The system boundaries of carbon footprints included upstream emissions including those from the production of all of crop inputs (e.g., fertilizer, pesticide, and seed) and on-farm emissions and removals associated with wheat production to the storage bin.

The range of carbon footprints for wheat production in Canada, the United States, and Australia are comparable when soil carbon sequestration is not included. When carbon sequestration is accounted for, the carbon footprint of wheat production in Canada is substantially reduced (Table 1).

Table 1 Range of average carbon footprints of wheat production per tonne of grain for the United States and Australia with and without accounting for soil organic carbon (SOC) sequestration.

Product	Net Emissions (kg CO_2e per tonne)
Canadian Wheat	343 – 600 (Bamber et al., 2023, CRSC, 2021, Desjardins et al., 2020, Gan et al., 2012)
Canadian Wheat (with SOC)	279 - 300 (Bamber et al., 2023; CRSC, 2021)
United States Wheat	300 – 790 (Bamber et al., 2023; Field to Market, 2021; Johnson et al., Shrestha et al., 2020)
United States Wheat (with SOC)	300 – 552 (Bamber et al., 2023; Shrestha et al., 2020)
Australian Wheat	453-544 (Bamber et al., 2023, Biswas et al., 2008)
Australian Wheat (with SOC)	287-544 (Bamber et al., 2023; Wang and Dalal, 2015)

Soil Organic Carbon Sequestration

Terminology:

Soil organic carbon (SOC) sequestration is the process by which CO_2, a major contributor to CO_2eq, is removed from the atmosphere and stored in soil as SOC. This process is mediated by plants via photosynthesis but can be augmented or diminished by agricultural management practices.

Agricultural management practices that promote the formation and persistence of SOC, such as conservation or no-till, cover cropping, and reduction of summer fallow, offset CO_2 emissions (Ozlu et al., 2022). In addition to offsetting emissions, agricultural practices that promote SOC sequestration also promote soil fertility (Feller et al., 2012), reduced erosion (Borrelli et al., 2016), improved soil water holding capacity (Lal, 2020), and mitigation of pesticide risk (Perez-Lucas et al., 2021). The carbon footprint of wheat production in Canada is substantially reduced when accounting for SOC sequestration (Table 1). Bamber et al. (2023) used country-specific national inventory data scaled by wheat yields to determine carbon sequestration and emission estimates per functional unit of crop and concluded that Canadian soils have net carbon sequestration, whereas the United States and Australia both have net carbon emissions from soils.

Based on an extensive national network of long-term field experiments and a long history of applied and fundamental research, Canada has developed a deep understanding of the nature and dynamics of SOC in its agricultural soils, their spatial distribution, and how SOC responds to management practices (Minasny et al., 2017). Long-term experiments have studied SOC changes over decades, resulting in reliable quantitative SOC information for agricultural soils in Canada (Table 2) (He et al., 2021). One such experiment is the Prairie Soil Carbon Balance Project (PSCB), which was initiated by the Saskatchewan Soil Conservation Association in 1997 to monitor SOC in agricultural soils across Saskatchewan that were converted from conventional tillage to no-till with continuous cropping. The findings of the PSCB conclusively show that SOC is increasing in the agricultural soils in Saskatchewan, a province with 75% adoption of no-till practices, more than 90% conservation tillage adoption and produces the most wheat in Canada (He et al., 2021; McConkey et al., 2020).

In comparison, the potential for wheat-growing agricultural soils of the United States to act as a sink has been acknowledged, however, most studies have quantified so-called potential magnitudes of SOC sequestration using various estimation methods (Minasny et al., 2017). A modelled estimate of actual soil carbon changes under wheat production systems under business-as-usual management concluded that soils in the United States under wheat production systems are net neutral, neither gaining nor losing carbon (Bamber et al., 2023). Similarly, Australian cropping soils are net neutral or a small net carbon sink under business-as-usual management, and the extent to which soil C storage can be increased in Australian agricultural soils by adoption of improved management practices is poorly understood (Bamber et al., 2023; Luo et al., 2019; Robertson and Nash, 2013) (Table 2).

Table 2 Measured and modelled data on the average changes soil organic carbon (SOC) on croplands growing wheat in Canada, United States, and Australia.

Region	Rate of SOC change[L] (Mg CO_2 per ac per yr)
Canada	0.04 – 1.25 (Campbell et al., 2005, Campbell et al., 2001a; Campbell et al., 2001b; He et al., 2021; Smith et al., 2001)
Australia	-0.57 – 0.57 (O'Donnell et al., 2009; Meisterling et al., 2009)
Australia	-0.97 – 0.73 (Lee et al., 2021; Luo et al., 2014; Robertson and Nash, 2013)

[L] Negative values denote losses of SOC (i.e., source of CO2), positive values indicate net SOC sequestration (i.e., sink of CO2)
[†] These values represent SOC change for wheat production in Western Canada

Of note, accounting for SOC change in carbon footprint calculations is increasingly complicated, because rates of SOC change are gradual; affected by current management practices, and by the amount of total SOC, the latter being a legacy of past land use management. Importantly, SOC maintenance or sequestration is reliant on continued adoption and maintenance of regionally suitable practices that facilitate the persistence of SOC, and if the C sequestration practice is ceased, SOC can be lost from soils at a rate faster than the C accrued. Additionally, the soil saturation concept suggests that rates of SOC accumulation slow over time, reaching a quasi-equilibrium state. Thus, when comparing different agricultural production systems, saturation effects may require consideration, as failure to do so may result in an overestimation of SOC sequestration potential (Nazir et al., 2024). Another way of assessing the carbon footprint of wheat production under different production systems is by comparing the carbon footprints on the basis of the protein content (Table 3).

Table 3 Average wheat protein production per acre for Canada, United States, and Australia

Region	Weighted average protein production (T of protein per ac)[L]
Canadian Wheat	0.20 (Cereals Canada, 2024; Canadian Grain Commission, 2023; Statistics Canada, 2024)
United States Wheat	0.15 (U.S. Wheat Associates, 2022; USDA, 2023c)
Australian Wheat	0.09 (AEGIC, 2022; USDA, 2023a)

[L] These values are calculations based on available data.

Wheat is classified not only by grade but also by desirable milling characteristics such as protein content within each individual grade. When considered on a protein basis, Canadian wheat has a comparatively low carbon footprint, namely when SOC sequestration is accounted for (Table 4).

Table 4 Range of average carbon footprints of wheat production per kilogram of protein for Canada, United States, and Australia with and without accounting for soil organic carbon (SOC) sequestration.

Region	Calculated Protein Footprint (kg CO_2eq per kg of protein)[L]
Canadian Wheat	2.6 – 4.5 (Bamber et al., 2023, CRSC, 2021, Desjardins et al., 2020, Gan et al., 2012, Cereals Canada, 2024, Canadian Grain Commission, 2023)
Canadian Wheat (with SOC)	2.1 – 2.3 (Bamber et al., 2023; CRSC, 2021 Cereals Canada, 2024, Canadian Grain Commission, 2023)
United States Wheat	2.5 – 6.6 (Bamber et al., 2023; Field to Market, 2021; Johnson et al., 2015; Shrestha et al., 2020; U.S. Wheat Associates, 2022)
United States Wheat (with SOC)	2.5 – 4.9 (Bamber et al., 2023; Shrestha et al., 2020; U.S. Wheat Associates, 2022)
Australia Wheat	4.2 – 5.6 (Bamber et al., 2023, Biswas et al., 2008; AEGIC, 2022)
Australian Wheat (with SOC)	2.7 – 5.6 (Bamber et al., 2023; Wang and Dalal, 2015; AEGIC, 2022)

[L] These values are calculations based on available data.

Fertilizer Use and Nutrient Use Efficiency

Increasing agricultural productivity remains the most viable pathway for attaining the great challenge of feeding 9.8 billion people by 2050, of which a food production increase of at least 70% is required (Alexandratos and Bruinsma, 2012; Dimkpa et al., 2020). Plants require nutrients such as nitrogen (N), phosphorus (P), and potassium (K) for optimal growth and productivity. Without fertilizer, intensive agricultural production would result in soil nutrient mining and long-term soil nutrient depletion, thus fertilizer application maintains soil fertility by replenishing nutrients removed during harvest (Tenorio et al., 2020). Simultaneously, fertilizer production results in the release of greenhouse gases (GHGs) and inefficient application of fertilizer can lead to environmental impacts (Gao and Serrenho, 2023). Therefore, carefully balancing crop nutrient requirements for global food security with soil fertility and environmental considerations is a significant challenge faced by Canadian farmers. Table 5 presents typical nutrient application rates for wheat production in Canada, the United States, and Australia.

Table 5 Average application rates of nitrogen (N), phosphorus (P) and potassium (K) for wheat production in Canada, United States, and Australia

Region and crop	N application (lb N per ac)	P application (lb P per ac)	K application (lb K per ac)
Canada (Fertilizer Canada, 2022)	103	28	7
United States (Ludemann et al., 2022; USDA, 2022a)	74	21	5
Australia (Angus and Grace, 2017; Ludemann et al., 2022)	40	22	3

Application rates of N, P, and K for wheat production are generally higher for Canada compared to the United States given that the majority of wheat produced by the United States and Australia is fertilized at lower N rates to ensure the lower protein levels for which it is grown. As a result, Canadian wheat has 33% and 120% greater protein, on average, compared to the United States and Australia. Additionally, Australian wheat is generally fertilized at much lower rates in part due to limited moisture that constrains yields (Vocke and Ali, 2013; Global Yield Gap Atlas, n.d.a). As such, average wheat yields in Australia are just under ~ 1 tonne per acre, whereas yields in Canada are on average 30% greater (USDA, 2023a).

Fertilizer application rates alone cannot fully assess the sustainability of agroecosystem fertilizer use. Understanding fertilizer use management is key. Improving fertilizer use efficiency by optimizing nutrient management is an important strategy to simultaneously increase the economic and environmental sustainability of crop production, by ensuring that fertilizer is properly taken up by crops.

Farmers in Canada make key decisions on fertilizer type, rate, timing, and placement that best suit the soils, weather, and farming operations within which they operate (Mezbahuddin et al., 2020). Compared to the rest of the world, Canada is one of the world leaders in nutrient use efficiency, with an average nitrogen use efficiency of approximately 51%, well above the global average of 35% (Karimi et al., 2020; Omara et al., 2019).

Nutrient balances can be a useful metric by quantifying nutrient flows and representing the nutrient use efficiency of agricultural systems (Ludemann et al., 2023).

Terminology:

Nutrient balance is calculated as the difference between nutrient inputs and outputs and is therefore an indicator of excess or insufficient use of nutrients from fertilizers and other sources in crop production (Ludemann et al., 2023; OECD, 2023).

Nutrient deficit (negative value) indicates declining soil fertility.

Nutrient surplus (positive value) indicates an excess of nutrient. The greater the nutrient surplus, the greater the chance of impacts to soil, water, and air.

Comparable data on soil nutrient budgets is a useful tool to assess and monitor agricultural performance between countries, such as the country-specific nutrient balances for N and P summarized in Table 6.

Table 6 5-yr average nutrient balances of nitrogen (N) and phosphorus (P) for croplands in Canada, United States, and Australia from OECD (2023).

Region	N balance (lb N per ac)	P balance (lb P per ac)
Canada	24	1
United States	24	2
Australia	17	1

An additional method to evaluate sustainable nutrient use in agroecosystems is through indicators such as the Sustainable Nitrogen Management Index (SNMI) (Table 7).

Table 7 The Sustainable Nitrogen Management Index (SNMI) for croplands in Canada, United States and Australia from EPI (2022).

Region	SNMI
Canada	67.3
United States	71.9
Australia	42.9

Critically, sustainable nutrient use also must consider that fertilizer is an essential input for agricultural crops, driving yield gains and subsequently supporting global food security (Kopittke et al., 2019). To represent the need to balance both food production and environmental protection, Zhang et al. (2022b) developed the unitless SNMI, which is a metric that combines the performance in crop yield and N use efficiency to evaluate country-specific sustainable N management. A score of 100 indicates that a country is optimizing both crop yields and fertilizer application, and a score of 0 indicates a country has among the worst performance on the SNMI (EPI, 2022).

Overall, both the nutrient balance and the SNMI demonstrate that Canada and the United States have comparable nutrient sustainability metrics. Conversely, Australian croplands have a lower N balance due to reduced N fertilizer application rates, but a lower SNMI due in part to lower crop yields than Canada and the United States.

Irrigation Water Use

Irrigation has multiple benefits, including increasing crop yields and yield stability and permitting the diversification of crop rotation, which is considered a best management practice to increase SOC stocks and promote soil biodiversity (Zhang et al., 2021). Simultaneously, globally increasing water demands from the agricultural sector are confounded by threats of overexploitation and inefficient management of water resources, which threatens the resource base upon which agriculture is dependent (De Fraiture and Wichelns, 2010). This underscores the importance of effective consumption of irrigation water, and the need for sustainable water management by the agricultural sector.

In Canada, only a small portion of total cropland is irrigated, with only approximately 5% of total wheat area receiving irrigation (Global Yield Gap Atlas, n.d.b). Overall, irrigation water withdrawals in Canada are negligible in the context of water availability (Bhatti et a., 2021). As irrigation pressures are minimal, existing water withdrawals tend to be lower than those in other wheat producing areas (Table 8).

Table 8 Irrigation water usage for wheat production in Canada, United States, and Australia

Region	Irrigation water usage (GL per year) [L]
Canada	~315-388 (Statistics Canada, 2023c, 2023d, 2023e)
Australia	691 – 1292 (Australian Bureau of Statistics, 2021, 2022, 2023; USDA, 2023)
United States	~1400 (Ruess et al., 2023)

[L] *These values are calculations based on available data.*

A greater portion of cropland in the United States, approximately 15-20%, is irrigated. However, most irrigation in the United States is used for grain corn and soybean production, whereas most wheat is grown under dryland conditions (USDA, 2023b; Vocke and Ali, 2013). When irrigation is used for wheat production, the majority is grown in the northwest part of the country, where approximately 20% of wheat produced in this region is irrigated (Vocke and Ali, 2013).

Irrigation is a useful tool for agricultural producers in Australia. Despite this, currently less than 10% of total arable land is equipped for irrigation in Australia (Australian Government, 2021; Muleke et al., 2022). Critically, while irrigation contributes to a more resilient crop production sector, Australia is prone to severe water scarcity and therefore strong consideration must be paid to the trade-offs between human needs and conservation of natural capital (Borsato et al., 2020).

Pesticide Use

Pesticides include a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, and nematicides, which have a longstanding and particularly important role in agriculture by protecting crops and improving productivity (Aktar et al., 2009).

Pesticides play an important role in modern agriculture and global food security, as they allow farmers to grow more food on the same land base by reducing weed, disease, and insect pressure and competition for resources, thus preventing increased conversion of land into agricultural land and protection of native ecosystems (Vicini et al., 2021). The ability to increase crop yield and improve crop production practices relies on pesticides. Pesticides help to decrease the need for other weed control methods like tillage, keep carbon in the soil, and reduce the use of farm equipment, therefore reducing fossil fuel use (Duke, 2020; Krimsky, 2021; Damalas and Eleftherohorinos, 2011).

Pesticides are strictly regulated in Canada to ensure their safety for human health and the environment. Indeed, Canada has one of the most stringent regulatory systems in the world for pesticides. Effective management of pesticide use mitigates pesticide risk while providing farmers with the tools they require to provide society with reliable access to safe and nutritious food.

Globally, the most widely used chemical herbicide is N-(phosphonomethyl) glycine, commonly referred to as glyphosate (Kolakowski et al., 2020). Glyphosate, the active ingredient in Roundup® brand herbicides, works by inhibiting an enzymatic process in plants, bacteria, and fungi that is absent in mammals and birds (Vicini et al., 2021). In Canada, glyphosate is subject to rigorous science-based assessments by Health Canada scientists before being approved for use and must be re-evaluated on a regular basis to ensure it does not present risks of concern to human health or the environment when used according to label directions. The most recent re-evaluation was conducted in 2017, followed by a statement in 2019 wherein Health Canada reiterated that the scientific basis for the 2017 re-evaluation decision for glyphosate was sound.

Similarly, the United States Environmental Protection Agency reviews pesticide approvals on a 15-year cycle, most recently re-approving glyphosate for use in January 2020 following an extensive review of the herbicide's safety and potential impacts on human health and the environment. The Australian Pesticides and Veterinary Medicines Authority (APVMA) is responsible for assessing the safety of glyphosate products, and most recently considered evidence for a formal reconsideration of glyphosate i n 2017, which concluded after a rigorous risk-based assessment that there is no scientific basis to revise the existing registrations for glyphosate-containing products (APVMA, 2017).

Glyphosate use in Canada, the United States, and Australia is subject to comparable label application rates for analogous products, reflecting similar usage guidelines between the three countries (Table 9).

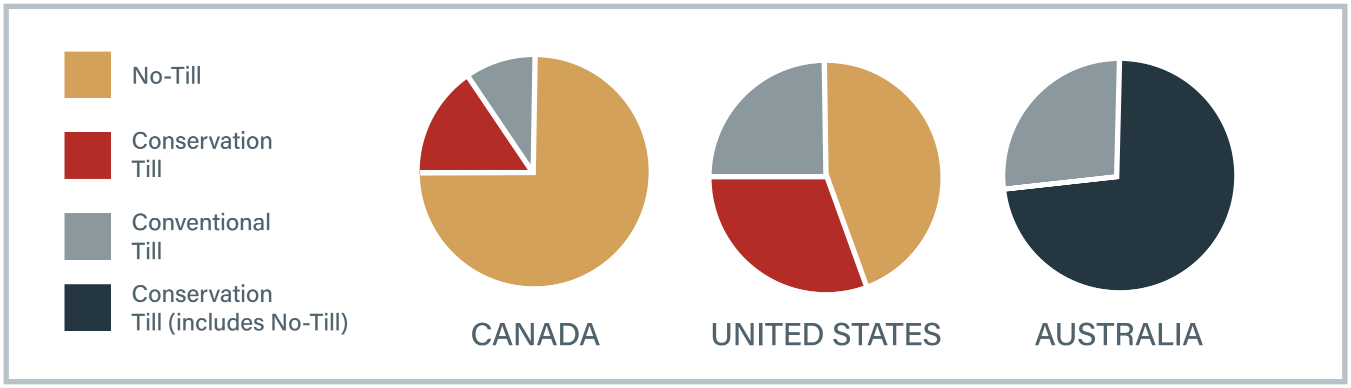
Table 9 Label use rates for comparable glyphosate-containing products in Canada, the United States, and Australia.

Region	Roundup Brand Product(s)	Application rate (lb acid equivalent per ac)
Canada	Roundup Transorb Roundup Weathermax	0.24 – 3.84 (Bayer, 2020b; Bayer, 2020c)
United States	Roundup Powermax 3 Roundup Powermax Roundup Weathermax	0.16 – 2.85 (Bayer 2020a; Pioneer, 2023)
Australia	Roundup Roundup Ultra MAX	0.40 – 2.57 (Sinochem Australia, 2015; Bayer Australia, n.d.)

Soil Erosion

Conservation management practices on agricultural lands include, but are not limited to, conservation or no-till management, diversification of crop rotations, cover cropping, and the establishment of vegetative buffer strips and grassed waterways (Stang et al., 2016). These practices, or combinations thereof, can be applied to maintain or improve soil health depending on their regional and production system suitability, as optimum soil management practices differ from one soil to another (Norris et al., 2022). Canadian wheat is grown from coast to coast; therefore, different conservation management practices have been implemented in areas that best suit their adoption.

Figure 2 Proportion of cropland under different tillage regimes for Canada, United States, and Australia. Note that for Australia, values for no-till and conservation tillage are combined (Statistics Canada, 2022b; USDA, 2022b; Llewellyn and Ouzman, 2020).



Cover crops are crops that cover the soil that are used to maintain or improve soil functionality by controlling soil erosion due to wind and water and nitrogen leaching (Shirriff et al., 2020).

Over 80% of winter wheat is grown in Ontario and leads the country in cover crop adoption.

Additionally, cover crops improve agroecosystem diversity, which increases system resilience (Shirriff et al., 2020). Cover crop adoption is supported and promoted by the Ontario Cover Crops Steering Committee, a group of farmer, commodity, and conservation organizations, which have developed a Cover Crops Strategy for Ontario that encourages widespread adoption of cover crops on farms in Ontario. Over one-third of farms in Ontario used fall or winter cover crops as a land management practice as of 2021, a figure which has significantly increased over the past decade (McComb et a., 2023; Statistics Canada, 2023a).

Western Canadian farmers in the prairie provinces of Alberta, Manitoba, and Saskatchewan grow more than 98% of spring wheat in Canada (Statistics Canada, 2025b). Over the past 25 years, producers in the prairies have transitioned away from using tillage as the dominant form of weed control, which has resulted in soil moving from being a net emitter of carbon to sequestering carbon as SOC (Sutherland et al., 2021).

Approximately 75% of Saskatchewan cropland is under no-till management, positioning wheat production systems in Canada a global leader in no-till adoption. Saskatchewan accounts for approximately 40% of Canada's wheat production. (Figure 2) (Congreves et al., 2015; Statistics Canada, 2022b, Statistics Canada, 2025b).

No-till adoption statistics are similar for Australia. According to the Australian government, approximately 68% of farms minimize tillage (ABERES, 2024; Llewllyn and Ouzman, 2020). Comparatively, no-till adoption in North Dakota and Kansas, the states which grow the majority of wheat in the United States, is 45% and 48%, respectively (USDA, 2022b; LaRose and Myers, 2019).

A key element of sustainable wheat production is conservation soil management, which requires minimizing and mitigating soil erosion (Poesen, 2018; Sartori et al., 2019). Soil erosion is recognized as a major environmental problem causing a loss of topsoil and nutrients, reduced soil fertility and consequently reduced crop yields (Telles et al., 2011; Zhao et al., 2013). Soil erosion can also increase SOC turnover and therefore increase emissions of CO_2 (Lugato et al., 2018).

Overall, soil erosion in Canada has declined in recent years, most drastically in the prairie provinces of Alberta and Saskatchewan, which experienced an increase in the share of cropland under the very low erosion risk class from 49% in 1981 to 86% in 2006 (Table 10) (Lobb et al., 2016).

Table 10 Cropland soil erosion rates based on measured and modelled data for Canada, United States, and Australia

Region	Erosion rate
Canada	Average cropland erosion rates of 0.3 t per ac per yr, with 80% of Canada's cropland erosion risk classified as very low (< 2.5 t per ac per yr). (Badreldin and Lobb, 2023; Li et al., 2010; McConkey et al., 2010; Zarrinabadi, 2023).
United States	Cropland erosion rates of 4.2 – 5.4 t per ac per year (USDA, 2017; Kertis and Livari, 2006).
Australia	Cropland erosion rates of 0.5 – 2.7 t per ac per year (Government of Western Australia, 2013; Tan et al., 2021; Zhang, 2022a).

This is largely due to the adoption of conservation management practices by Canadian producers that minimize erosion risk (Awada et al., 2021; Fox et al., 2012; McConkey et al., 2010).

Soil erosion in the United States has also declined since measurements began, but erosion rates have stabilized in recent years with annual losses of approximately 1700 million tons of soil lost yearly (USDA, 2017). Thaler et al. (2022) concluded that soil erosion rates in the Midwest are unsustainable, but not unique to the study area and efforts must be taken at a greater scale to combat soil erosion, including the incentivization of no-till farming in areas where barriers to its implementation persist.

Australian agricultural soils are particularly vulnerable to degradation processes including erosion, which is occurring at unsustainable rates and has a critical impact on agricultural productivity (Bui et al., 2011; Pereira et al., 2023). An inherently variable climate, combined with sparse vegetation cover over about much of the continent, and the typically poorly structured, shallow, and infertile topsoil make the Australian continent susceptible to erosion, namely in the zones of intensive land use. Erosion rates have been significantly reduced over time due to implementation of best management practices, but continued improvement in groundcover management is needed to minimise erosion risk under a drying climate (OECD, 2015).

Conclusions

Sustainability is one of the defining concepts of agriculture today. It is both a major challenge as well as an opportunity for Canada to be a global leader in the provision of high quality, nutritious, and sustainable products, namely wheat.

Canadian farmers have responded to demands for sustainable food production, as evidenced by the widespread adoption of regionally specific conservation management practices, which have resulted in Canadian soils sequestering vast amounts of SOC and becoming a substantial CO_2 sink. Because of this, the carbon footprint of wheat production in Canada is generally smaller than in the United States or Australia when measured as tonnes of wheat grown and by tonnes of wheat protein produced. Additionally, conservation management practices have substantially reduced erosion rates on Canadian croplands.

Overall, Canadian wheat production boasts several sustainability advantages compared to other major wheat producing areas.

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