CEREALS CANADA

Environmental Sustainability of Canadian Durum Wheat

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Contents

3 List of Figures

3 List of Tables

3 List of Maps

4 Executive Summary

6 Assessing the Sustainability of Canadian Durum Wheat

8 The Carbon Footprint of Canadian Durum Wheat

9 Soil Organic Carbon Sequestration

11 Fertilizer Use and Nutrient Use Efficiency

13 Irrigation Use

14 Pesticide Use

16 Soil Erosion

18 Conclusion

19 References

List of Figures

Figure 1
Six science-based indicators to evaluate the sustainability of Canadian durum wheat production relative to production of durum wheat in Italy and the United States.

Figure 2
Proportion of cropland under different tillage regimes in Saskatchewan, United States, and Italy (Sutherland et al., 2021; Eurostat, 2024; Claassen et al., 2018).

List of Maps

Map 1
Wheat Production Areas in Canada

Map 2
Soil Zones of Canadian Prairies

Map 3
Durum Wheat Production in Italy

Map 4
Durum Wheat Production in United States

List of Tables

Table 1
Estimated net carbon footprints for wheat production for Canada, Italy, and United States with and without accounting for soil organic carbon (SOC) sequestration.

Table 2
Range of measured and modelled data on the changes in SOC on croplands growing wheat in Canada, Italy, and United States.

Table 3
Estimated protein production per acre for Canada, Italy, and United States.

Table 4
Estimated carbon footprints of wheat production per kilogram of protein for Canada, Italy, and United States with and without accounting for soil organic carbon sequestration.

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

Table 6
Five-year average nutrient balances of nitrogen (N) and phosphorus (P) for agricultural land in Canada, Italy, and United States from OECD (2023).

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

Table 8
Irrigation water usage for durum wheat production in Canada, Italy, and United States as a function of total durum wheat production area.

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

Table 10
Soil erosion rates based on measured and modelled data for Canada, Italy, and United States.

Executive Summary

Canada is the world's leading producer of durum wheat, with an average seeded area of 6 million acres of annual durum production, and a 5-year average production of 5.1 million tonnes (Statistics Canada, 2025). Canadian durum wheat is grown in the southern prairies of Western Canada, primarily in the provinces of Alberta and Saskatchewan.

Map 1

Wheat Production Areas

CANADA

COMMON WHEAT

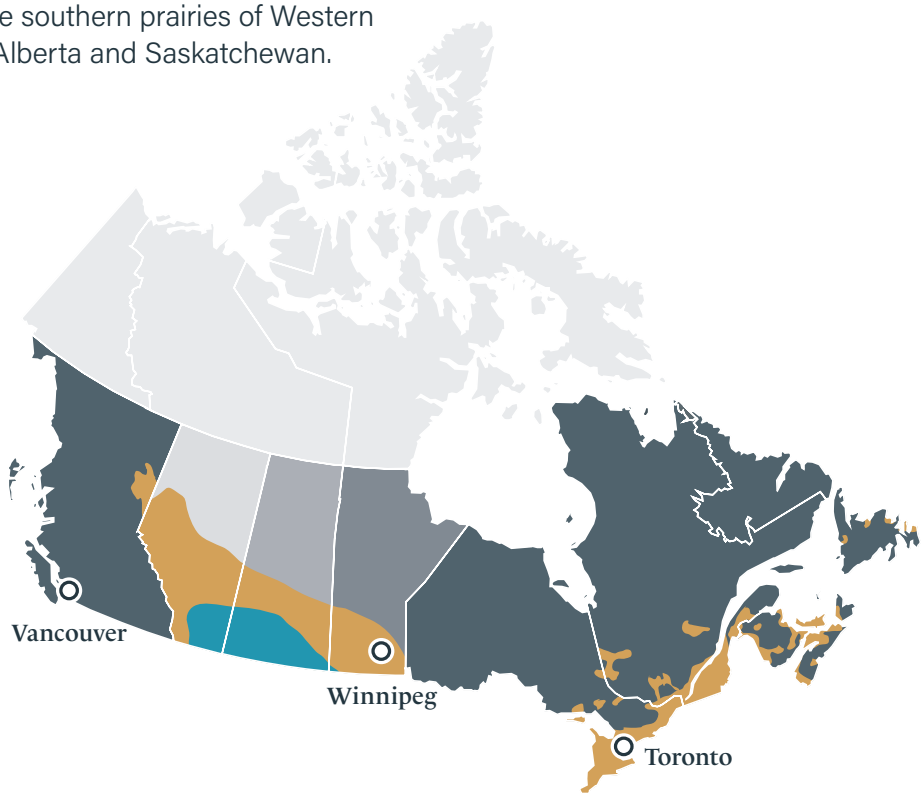
DURUM WHEAT

AB

SK

MB

Other



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 foremost challenges facing agriculture. In this situation of growing awareness, increasing emphasis on environmentally 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 environmental sustainability of the production of a key Canadian agricultural commodity, durum wheat.

Cereals Canada compares the sustainability of Canadian durum wheat production systems to two other major durum wheat production systems: Italy and United States, using six sustainability indicators: soil carbon sequestration, carbon footprint of durum wheat production, fertilizer use and efficiency, irrigation water use, pesticide use, and soil erosion.

Executive Summary

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

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

1. The carbon footprint of durum wheat per tonne of grain and a per kilogram of protein production in Canada is substantially lower compared to the carbon footprint of durum wheat produced in Italy or the United States when accounting for soil organic carbon (SOC) sequestration.

2. Canadian cropland soil is a carbon dioxide (CO_2) sink, with a 5-year average CO_2 sequestration of 14.2 million tonnes per year. Additionally, Canada grows high quality, high protein durum wheat. Canadian farmers produce the highest tonnes of protein per acre of durum wheat grown. The result of this is a very low carbon footprint per kilogram of protein produced.

3. Application rates of nitrogen (N), phosphorus (P), and potassium (K) fertilizer for durum wheat production are generally lowest in Canada when compared to Italy and the United States. Further, both the nutrient balance (from the Organization for Economic Cooperation and Development [OECD]) and the sustainable nitrogen management index (from the Environmental Performance Index [EPI]) demonstrate that Canada and the United States have comparable nutrient sustainability metrics, both surpassing Italian agroecosystems in terms of sustainable nutrient management.

4. In Canada, irrigation pressures are minimal, and existing water withdrawals are estimated to be lower than those for durum wheat production in Italy and United States. Canadian irrigation water use for durum wheat production is an order of magnitude lower than that of Italy or the United States.

5. Pesticides are used for durum wheat production in Canada, Italy, and the United States. Glyphosate is an herbicide approved for use in all three countries and is subject to comparable label application rates for analogous products for control of annual and perennial weeds in cereal production systems.

6. Canada leads in adoption of soil conservation management practices, with 75% adoption of no-till in the largest durum producing province, compared to 45% adoption in North Dakota, and only approximately 20% adoption of no-till in Italy. Soil erosion in Canada has declined drastically in the provinces of Alberta and Saskatchewan where durum wheat is primarily cultivated. Canadian producers are leaders in the adoption of conservation management practices that minimize erosion risk, such as no-till and reduced summer fallow.

Overall, 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 durum 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 durum producers and the Canadian agricultural sector as a whole.

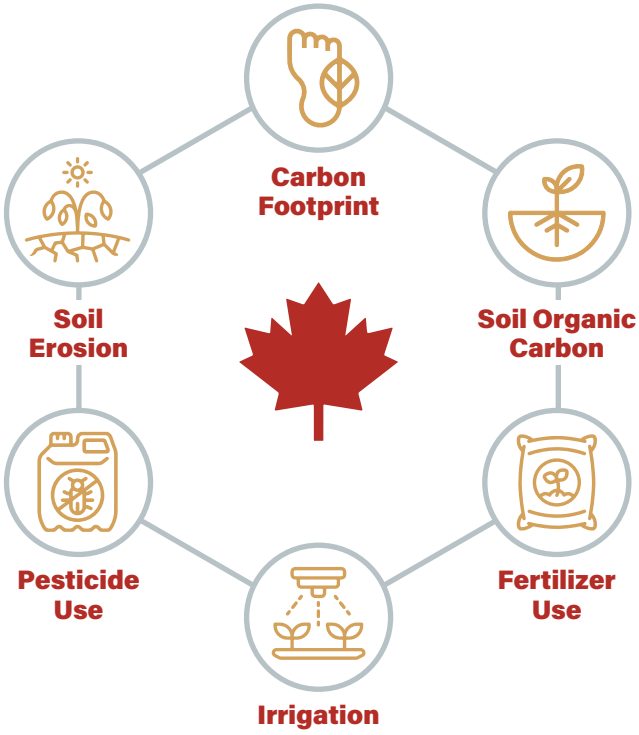
Assessing the Sustainability of Canadian Durum Wheat

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 environmental 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).

Canada is the world's leading producer of durum wheat, with an average seeded area of 6 million acres, and a 5-year average production of 5.1 million tonnes (Statistics Canada, 2025). Canadian durum wheat is grown in the southern prairies of Western Canada, primarily in the provinces of Alberta and Saskatchewan.

To evaluate the environmental sustainability of Canadian durum wheat production, Cereals Canada has chosen 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 durum wheat production (Latruffe et al., 2016). The selected indicators rely on robust data, recognizing that their development is subject to data availability.

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

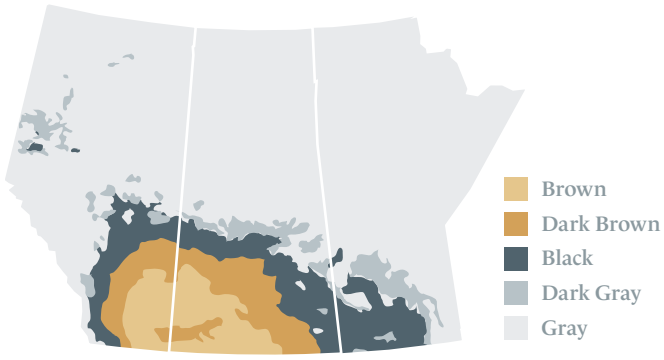


For each indicator, durum-specific data were used when possible, however, when data availability precluded this, Cereals Canada has indicated have indicated when wheat or cropland-specific data were used. The selected indicators were then applied to two other major durum producing regions: Italy and the United States, to comparatively evaluate the sustainability of Canadian Durum production. The direct comparison of environmental indicators between nations is nuanced 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 durum wheat production in a broader context.

Durum wheat is primarily grown in the Western Canadian provinces of Alberta and Saskatchewan, with small areas of production in Manitoba (Li et al., 2018). In general, the durum wheat growing region is characterized by its aridity (McGinn, 2010). There are five soil zones (Brown, Dark-Brown, Black, Dark-Gray and Gray) with a general precipitation gradient along these soil types; the Brown soil zone is the most arid and the Black/Gray zones are wetter and cooler, resulting in higher soil organic matter (Awada et al. 2021).

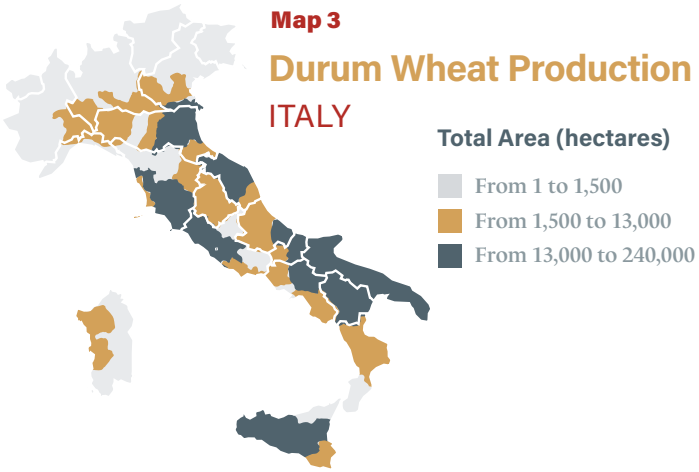
Map 2

Soil Zones of the Canadian Prairies



Map 3

Durum Wheat Production
ITALY

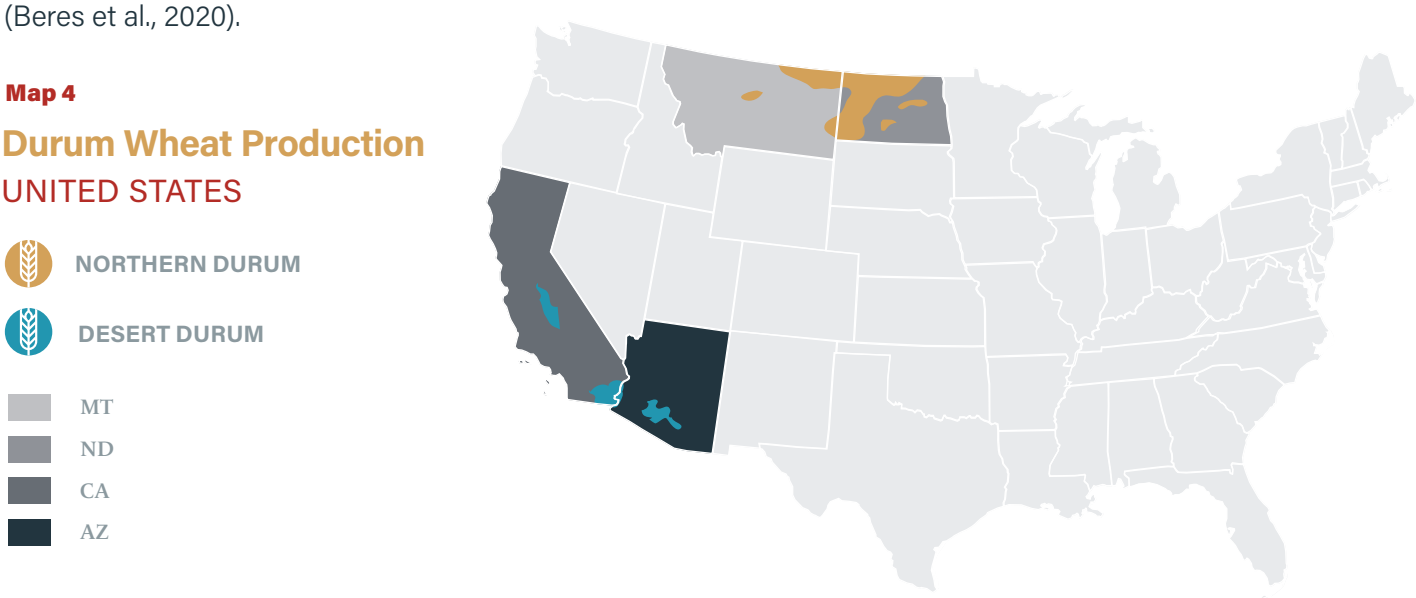


In Italy, durum wheat production is concentrated in southern and central Italy, where mediterranean and humid subtropical climates are dominant (Mariani et al., 2021). Alluvial soils dominate the intensively cultivated soils of the southernmost part of the coastal plains and in the valleys of the central and southern hills, soils developed from volcanic materials are heavily utilized for agricultural production (Costantini et al., 2004).

The vast majority of durum wheat production in the United States is in the Northern Plains region, where the climate is similar to Canadian durum wheat growing regions, with short hot summers and low precipitation, and topsoil with high organic matter (2-8%) (Padbury et al., 2002). Smaller amounts of durum wheat known as Desert Durum are grown on irrigated land in the desert valleys of Arizona and California (Beres et al., 2020).

Map 4

Durum Wheat Production
UNITED STATES



The Carbon Footprint of Canadian Durum Wheat

As a favored food source, maintaining and increasing production of durum wheat is paramount. Durum wheat is currently the 10th most important and commonly cultivated cereal worldwide with a yearly production average of 40 million tonnes (Beres et al., 2020). Agricultural management that minimizes the carbon footprint of agricultural commodities is the key to sustainably managing the trade-off between food production and greenhouse gas (GHG) emissions.

Terminology:

Carbon footprint is the sum of GHG emissions related directly and indirectly to 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 our estimates. The system boundaries of carbon footprints include 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 durum wheat production to the farm gate.

Carbon footprints for durum wheat production in Canada, the United States, and Italy are comparable within a range when soil carbon sequestration is not included (Table 1).

Table 1 Estimated carbon footprints for wheat production per tonne of grain for Canada, Italy, and the United States with and without accounting for soil organic carbon (SOC) sequestration.

Product	Net Emissions (kg CO_2e per tonne)
Canadian Durum	241 - 420 (Bamber et al., 2023; CRSC, 2021a; Gan et al., 2011a, 2011b)
Canadian Durum (with SOC)	70 – 155 (Bamber et al., 2023; CRSC, 2021a)
Italian Durum	223 – 741 (Ali et al., 2015; Ali et al., 2017; Ruini et al., 2013; Ingrao et al., 2018)
Durum (with SOC)	741 (Bamber et al., 2023)
American Durum	250 (Bamber et al., 2023)
American Durum (with SOC)	309 (Bamber et al., 2023)

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, facilitate the mitigation of CO_2eq emissions by offsetting emissions (Ozlu et al., 2022).

In addition to offsetting CO_2eq 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 leaching. (Pérez-Lucas et al., 2021). Thus, continued adoption of practices that maximize SOC by Canadian farmers is a cornerstone of Canadian agricultural sustainability and has resulted in Canadian cropland being a sink for CO_2 at a rate of 14.2 million tonnes per year (5-year average) (ECCC, 2023). Thus, the carbon footprint of durum 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 durum wheat yields to determine carbon sequestration and emission estimates per functional unit of crop and concluded that inclusion of SOC reduced the carbon footprint of durum wheat production in Canada by 57%.

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 no-till in the agriculture soils in Saskatchewan, a province with 75% adoption of no-till practices, more than 90% conversation adoption and produces the majority of durum wheat in Canada (approximately 84%) (McConkey et al., 2020; Awada et al., 2021; Statistics Canada, 2022a).

In comparison, the potential for 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). Similarly, numerous studies have identified the potential for Italian soils to sequester SOC, but estimates suggest that in general agricultural soils in the European Union are a net source of CO2 from SOC loss (Table 2) (European Environment Agency, 2023). Using the RothC model, Mondidi et al. (2012) determined that business as usual management of agricultural soils in Italy results in losses of SOC of 7.4% by 2100, on average.

Table 2 Range of measured and modelled data on the changes in SOC on croplands growing wheat in Canada, Italy, and the United States.

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)[†]
Italy	-0.45 – 0.97 (Bleuler et al., 2017; Di Bene et al., 2016; Farina et al., 2017; Khan et al., 2022; Valkama et al., 2020; Novara et al., 2016)
United States	-0.57 – 0.57 (O'Donnell et al., 2009; Meisterling et al., 2009)

[L] *Negative values denote losses of SOC (i.e., source of CO_2), positive values indicate net SOC sequestration (i.e., sink of CO_2)*

[†] *These values represent SOC change for durum growing regions in 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 sequestration is reliant on continued adoption and maintenance or beneficial practices, as once the carbon sequestration practice is ceased, SOC can be lost from soils at a rate faster than the carbon accrued.

Another way of assessing the carbon footprint of durum wheat production under different production systems in Canada, Italy, and the United States is to calculate the carbon footprints in terms of kg of protein produced using estimates of the protein produced per acre (Tables 3,4). When considered on a protein basis, Canadian durum wheat generally has the lowest carbon footprint, namely when SOC sequestration is accounted for.

Table 3 Estimated protein production per acre for Canada, Italy, the United States.

Region	Weighted average protein production (T of protein per ac)[L]
Canadian Durum	0.15 (Cereals Canada, 2024; Canadian Grain Commission, 2023; AAFC, 2023)
Italian Durum	0.15 (Careddu et al., 2023; I.Stat, 2024)
American Durum	0.17 (U.S Wheat Associates, n.d.; USDA, 2023)

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

Table 4 Estimated carbon footprints of wheat production per kilogram of protein for Canada, Italy, and the United States with and without accounting for soil organic carbon sequestration.

Region	Calculated Protein Footprint (kg CO_2eq per kg of protein)[L]
Canadian Durum	1.7 - 3.0 (Gan et al., 2011a; Gan et al., 2011b; CRSC, 2021a; Bamber et al., 2023; Cereals Canada, 2023; Canadian Grain Commission, 2023)
Canadian Durum (with SOC)	0.5 – 0.7 (CRSC, 2021a; Bamber et al., 2023; Cereals Canada, 2024; Canadian Grain Commission, 2023)
Italian Durum	1.9 – 6.8 (Ali et al., 205; Ali et al., 2017; Ruini et al., 2013; Ingrao et al., 2018; Bamber et al., 2023; Careddu et al., 2024)
Italian Durum (with SOC)	6.8 (Bamber et al., 2023; Gagliardi et al., 2020)
American Durum	1.8 (Bamber et al., 2023; U.S. Wheat Associates, n.d.)
American Durum (with SOC)	2.2 (Bamber et al., 2023; U.S. Wheat Associates, n.d.)

[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). Therefore, carefully balancing crop nutrient requirements for global food security with soil fertility is a significant challenge faced by farmers. Table 5 presents typical nutrient application rates for wheat and durum production in Canada compared Italy and the United States.

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

Region and crop	N application (lb N per ac)	P application (lb P per ac)	K application (lb K per ac)
Canadian durum wheat (CRSC, 2021a)	70	24	4
Italian durum wheat (Gadaleta et al., 2022; Ludemann et al., 2022)	107	26	2
United States wheat (incl. durum) (USDA, 2019)	78	34	5

While application rates of N, P, and K for durum wheat production are generally lowest in Canada, application rates alone cannot fully assess the sustainability of agroecosystem fertilizer use. Nutrient balances are a useful metric by quantifying nutrient flows and representing the resource 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 risk of adverse effects to soil, water, and air.

The nutrient balance is calculated as the difference between the nutrient inputs entering an agroecosystem and the nutrient outputs leaving the system (i.e., via harvest). 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 Five-year average nutrient balances of nitrogen (N) and phosphorus (P) for agricultural land in Canada, Italy, and the United States from OECD (2023).

Region	N balance (lb N per ac)	P balance (lb P per ac)
Canada	24	1
Italy	60	-2
United States	24	2

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

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

Region	SNMI
Canada	67.3
Italy	56.8
United States	71.9

Overall, both the nutrient balance and the SNMI demonstrate that Canada and the United States have comparable nutrient sustainability metrics.

Irrigation 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 efficient 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. Total irrigated cropland is considerably lower than Italy and United States. Of this, less than 1% of total durum wheat area receives irrigation in Canada. Overall, irrigation water withdrawals in Canada are negligible in the context of water availability. As irrigation pressures are minimal, existing water withdrawals tend to be lower than those in other durum wheat producing areas (Table 8) (Bhatti et al., 2021).

Table 8 Irrigation water usage for durum wheat production in Canada, Italy, and the United States

Region	Calculated water usage (thousand megalitres per yr)[L]
Canada	56 – 67 (Government of Alberta, 2023a; Saskatchewan Ministry of Agriculture, 2022; Statistics Canada, 2013; Statistics Canada 2023b)
Italy	~328 (Ceglar et al., 2021; Daccache et al., 2016; Vigani et al., 2016)
United States	357 – 401 (Beres et al., 2020; Frisvold et al., 2015; Johnson et al., 2015; USDA, 2018)

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

In the United States, durum wheat is cultivated in the Northern Great Plains as well as in the southwest states of California and Arizona. Agricultural production on the Northern Great Plains is primarily rainfed. However, irrigation is extensively utilized in the desert climate of the southwest for durum wheat production (Beres et al., 2020: U.S. Wheat Associates, 2021). In this region, the mismatch between irrigation demand and freshwater availability has resulted in an unsustainable depletion of surface and groundwater (Lopez et al., 2022).

The Mediterranean climate of Italy is characterized by chronic water shortage and irregular precipitation patterns. Thus, the adoption of supplementary irrigation is utilized to stabilize cereal production in the region (Todorovic et al., 2018). In Italy, where durum wheat cultivation can be undertaken in specific instances under rainfed conditions, it is done so in tandem with significant irrigation withdrawals for orchards and vegetable production (Bazzani et al., 2004; Dalla Marta et al., 2015).

Pesticide Use

Pesticides include a wide range of compounds including insecticides, fungicides, and herbicides, 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 agriculture and protection of native ecosystems (Vicini et al., 2021). Our ability to sustainably increase crop yield and close existing yield gaps depends on this intensification and assessing the net impact of pesticides must consider that pesticides decrease the need for other weed control methods such as tillage, thus increasing SOC retention and reducing fossil fuel use (Duke, 2020; Krimsky, 2021; Damalas et al., 2011).

Pesticides are strictly regulated in Canada to ensure their safety for human health and the environment. 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. As of December 2023, the European Union renewed the approval of glyphosate for 10 more years after a rigorous assessment that did not identify any critical concern.

Glyphosate use in Canada, the United States, and Italy is subject to comparable label application rates for analogous products, reflecting similar usage guidelines between the three countries (Table 9). Unlike Italy, glyphosate is registered for use post-emergence in Canada and the United States. Glyphosate is not registered for use as a desiccant in Canada. Post-emergence glyphosate applications must adhere to strict label guidelines for application rate, timing, and pre-harvest interval (Keep it Clean, 2024).

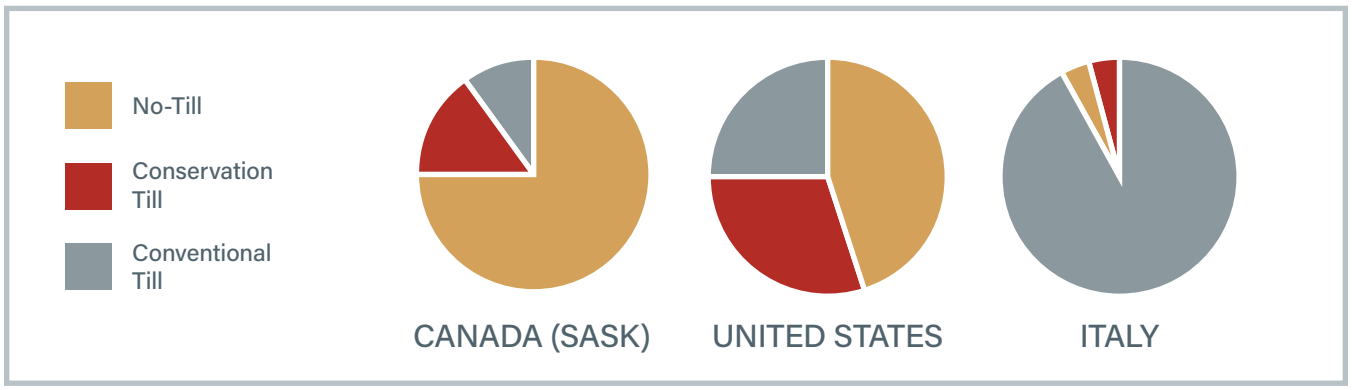
Table 9 Label use rates for comparable glyphosate-containing products in Canada, Italy, and the United States.

Region	Roundup Brand Product(s)	Application rate (lb equivalent per ac)
Canada	Roundup Transorb Roundup Weathermax	0.24 – 3.85 (Bayer 2020b, Bayer 2020c)
Italy	Roundup Power Roundup Platinum Roundup Ultramax	0.32 – 3.85 (Bayer 2020a, Bayer 2022)
United States	Roundup Powermax 3 Roundup Powermax Roundup Weathermax	0.75 – 3.75 (Pioneer, 2023; US EPA, 2022)

Soil Erosion

Over the past 25 years, Canadian durum wheat producers 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). Over two-thirds of the Canadian prairie provinces are under conservation tillage practices. Approximately 75% of Saskatchewan's cropland, which accounts for about 81% of Canada's durum wheat production, is managed using no-till practices. This positions Canadian durum wheat production as a global leader in the adoption of no-till agriculture (Figure 2) (Statistics Canada, 2022). Comparatively, no-till adoption in North Dakota, the state which grows 80% of the United States' durum wheat, is 45% and approximately 80% of Italian cropland remains under conventional tillage (USDA, 2022; US Durum Growers Association, 2021l Eurostat, 2016).

Figure 2 Proportion of cropland under different tillage regimes in Saskatchewan, the United States, and Italy (Sutherland et al., 2021; Eurostat, 2024; Claassen et al., 2018).



In combination with crop rotation, minimum or no-till practices adopted by durum wheat producers in Canada have maintained or enhanced soil health (Congreves et al., 2015).

Crop rotation is practiced by more than 95% of Canadian producers (Statistics Canada, 2023c). .Minimizing tillage and rotating crops is proven to improve soil biological, physical, and chemical properties for plant development. These benefits include increasing levels of soil organic matter, total nitrogen, soil biological activity, and soil physical quality parameters such as water infiltration rate, among many other advantages (Congreves et al., 2015).

Soil Erosion

A key element of sustainable durum 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 (Zhao et al., 2013; Telles et al., 2011). 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 durum-growing 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). This is largely due to the adoption of conservation tillage management practices by Canadian producers that minimize erosion risk, such as no-till and reduced summer fallow (Awada et al., 2021; Fox et al., 2012).

Table 10 Soil erosion rates based on measured and modelled data for Canada, Italy, and the United States.

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).
Italy	Cropland erosion rates ranging from 0.8 – 4.5 t per ac per yr., with 33% of cropland classified as under severe (> 4.5 t per ac per yr.) erosion (Capolongo et al., 2008; Capra and Scicolone, 2002; Cosentino et al., 2015; Panagos et al., 2020; Postiglione et al., 1990; Petito et al., 2022).
United States	Cropland erosion rates of 4.2 – 5.4 t per ac per year (USDA, 2017; Kertis and Livari, 2006)

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 current soil erosion rates in are unsustainable, and efforts must be taken at a greater scale to combat agriculturally induced soil erosion, including the incentivization of no-till farming in areas where barriers to its implementation persist.

Soil erosion is also an active challenge in Italy. This situation reflects the high susceptibility of the Italian landscape to erosion and agricultural management practices that exacerbate erosion risk, namely the limited adoption of conservation management practices (Borrelli et al., 2016).

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 environmentally sustainable products, including durum wheat. Canadian farmers have adopted new technologies and conservation management practices, such as the widespread adoption of no-till in the prairie provinces where durum wheat is cultivated, which has resulted in Canadian soils becoming a substantial net carbon sink. Because of this, the carbon footprint of durum wheat production in Canada is substantially lower compared to the carbon footprint of durum wheat produced in Italy or the United States. Additionally, durum wheat production in Canada uses less fertilizer inputs than Italian durum and produces more durum wheat with significantly less irrigation water than Italy or the United States. Thus, Canadian durum wheat maintains an overall sustainability advantage compared to other durum wheat producing areas.

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