CAPI
THE CANADIAN AGRI-FOOD POLICY INSTITUTE

Clean Growth in Agriculture

White Paper prepared for the Clean Economy Fund

by

Authors: Tulay Yildirim, Ted Bilyea, Don Buckingham
Research Assistance: Margaret Zafiriou
Creative Content: Elise Bigley, Louise de Vynck

Final Report
May 2019

The Canadian Agri-Food Policy Institute

960 Carling Avenue, CEF

Building 49, Room 318

Ottawa, ON K1A 0C6

Telephone: 613-232-8008

Fax: 613-232-8008

www.capi-icpa.ca

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1. Executive Report

Two major challenges facing the world in the 21st century are climate change and food security. Agriculture sits at the centre of the proverbial "eye of the storm" due to its contribution to greenhouse gas (GHG) emissions and climate change, and the impact climate change will have on agriculture and future food production. Also, there is great potential to significantly reduce net emissions by changing agricultural practices.

The challenge remains whether agricultural production can grow enough to produce nutritious, affordable, and accessible food to meet the demands of an increasing global population, without degrading the environment or depleting the natural resource base or "natural capital" (land, water, air, biodiversity).

In response to this challenge, the Canadian Agri-food Policy Institute (CAPI) organized three conversations in 2017-2018 that attempted to determine how the Canadian agricultural industry could best achieve sustainable growth.[1] CAPI concluded that "…we will require more than 'simple' growth to achieve the ambitious growth targets set out by the federal government's Advisory Committee on Economic Growth (ACEG), otherwise known as the Barton Report.[2] 'Quality' or 'clean' growth is needed to ensure that the gains in the agri-food sector can be sustainable for the future." [3]

This paper will explore the ways in which the Canadian agriculture sector can achieve "clean" growth. Four main components frame this report:

- *The current state of play between agriculture, the environment and climate change*
- *Policies, programs, and community-based initiatives in Canada that strive to mitigate the impact of agriculture on the environment*
- *Potential technological developments and innovative pathways to a zero-carbon economy; and*
- *Options to promote investments in this clean growth.*

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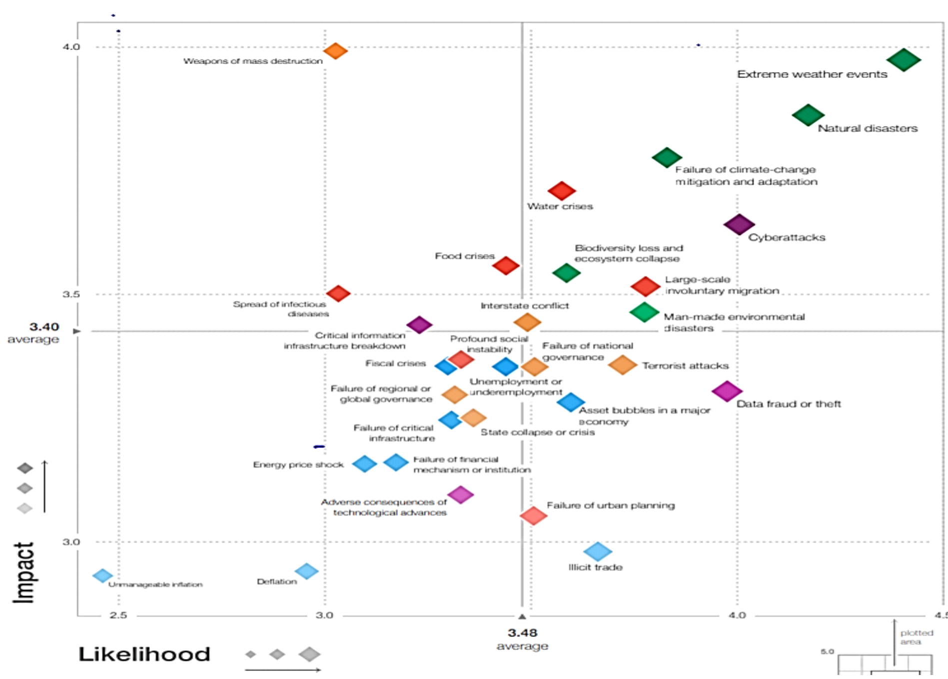
[1] CAPI, "What we heard, Barton Forward, Optimizing Growth in the Canadian Agri-food Sector," June 22, 2018, pg. 2. Accessed at: https://capi-icpa.ca/wp-content/uploads/2018/06/CAPI_Barton_WhatWeHeardReport_Eng.pdf.
[2] Dominic Barton was appointed by the government in 2016 as head of the Advisory Council on Economic Growth (ACEG) to "develop advice on concrete policy actions to help create the conditions for strong and sustained long-term economic growth." Accessed at: https://www.budget.gc.ca/aceg-ccce/home-accueil-en.html.
[3] CAPI, "What we heard, Barton Forward, Optimizing Growth in the Canadian Agri-food Sector," pg. 2.

The Global Context

Vibrant agriculture is key to feeding the world. Yet the impacts from food production are increasingly felt around the globe. “Feed the world or save the planet” is a stark choice, but if done well, modern agriculture and food systems hold the promise for doing both. If done sub-optimally, agriculture and food production pose significant risks to human health, animal, plant and microbial life and biodiversity, as well as air, water, and soil quality. Moreover, depending on the risk, local (think ground water contamination), regional (think biodiversity in ecozones) or international (think climate change) implications prevail.

From a production perspective, by 2050 it is predicted that the world’s population will rise to just under 10 billion and to meet the nutritional needs of these global citizens, we will have to grow as much food between now and then as the planet has produced up until the present.[4] According to the UN, global agricultural production will need to increase by 70% by 2050 in order to feed the projected global population. This will require increased yields from productivity growth as well as more environmentally sustainable production.[5]

Figure 1: Global Risks Landscape, WEF, 2019[6]



[4] Food and Agriculture Organization (FAO), “How to Feed the World in 2050,” 2009. Accessed at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf and UN, “World Population Prospects: the 2015 Revision,” 2015. Accessed at: http://www.un.org/en/development/desa/publications/world-population-prospects-2015-revision.html.

[5] FAO, “The Future of Food and Agriculture: Challenges and Trends,” 2017. Accessed at: http://www.fao.org/3/a-i6583e.pdf.

[6] World Economic Forum (WEF), Global Risks Report-2019, 2019, pg. 5. Accessed at: http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf.

From a risks perspective, the World Economic Forum (WEF) identified ten potential global crises that are most likely to occur and with the highest potential impact (Figure 1). Seven of the ten risks impact or are impacted by (or both) agriculture and food production: extreme weather events, natural disasters, failure of climate-change mitigation and adaptation, water crises, biodiversity loss and ecosystem collapse, man-made environmental disasters, and food crises.

According to the UN's estimates, on a global level, agricultural activities account for 60 per cent of terrestrial biodiversity loss, 24 per cent of greenhouse gas emissions, 33 per cent of soil degradation and 61 per cent of the depletion of commercial fish stocks since the 1970's.[7]

Despite recent short-term trade disputes and fluctuations, future growth opportunities for agricultural and food products are no doubt plentiful as the global demand for products continues to rise, and the fast-growing middle classes of emerging economies, such as those in Asia, demand more high quality, healthy food, at a time when the earth's capacity to produce is becoming more limited.

Decoupling economic growth and consumption from natural resource use will be needed to spearhead initiatives that move from mere growth to quality growth, or depending on how one uses terminology, to a clean growth strategy for the agriculture sector.[8] This would provide an opportunity for agriculture to make a major contribution to enhancing natural capital and the mitigation of climate change. The question remains, how do we make this happen?

The Canadian Context

Agriculture and Food Production in Canada

Canada is the world's second largest country in terms of land mass, and contains plentiful freshwater, forests and wildlife resources. However only 6.9% of land in Canada is considered dependable agricultural land, and only 4.8% is suitable for crop production, making it 15th in the world for total arable land.[9] Agricultural lands are generally clustered along Canada's southern-most geopolitical boundary, where there is adequate water and sunlight, suitable heat units, and sufficient mineral soils to support agricultural activity. The Prairie Region accounts for 60% of

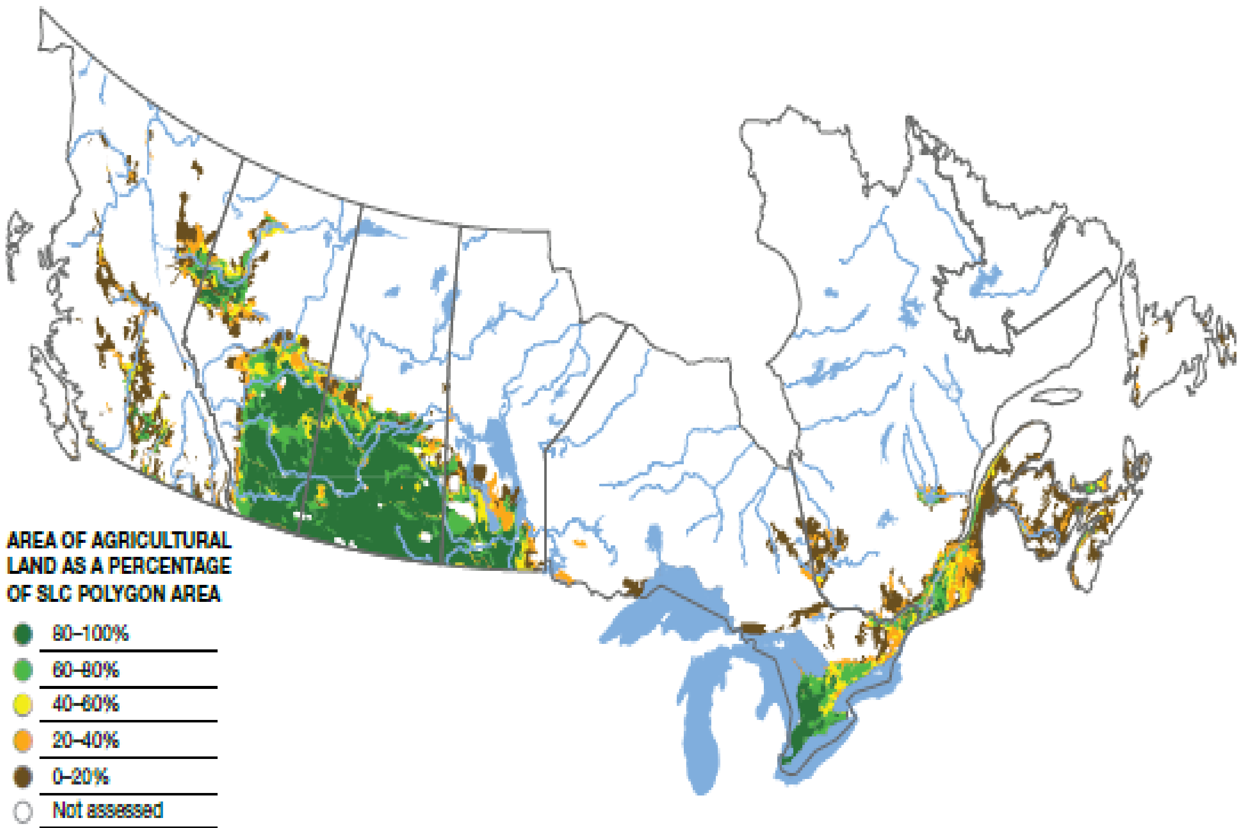
[7] FAO, "The State of Food and Agriculture: Climate Change, Agriculture and Food Security," 2016.

[8] ***Clean Growth*** is defined by Environment and Climate Change Canada (ECCC) as growth that allows us to meet our emissions reduction targets, grow the economy and build resilience to a changing climate at the same time. This compares with traditional ***Economic growth*** which is generally measured by a country's growth in output, as indicated by Gross Domestic Product (GDP). ***Quality growth***, such as defined in the "Barton Forward: What We Heard Report" ensures economic growth takes place without depleting natural capital to ensure future sustainability. ***Green growth*** is similar, defined by the Organization for Economic Cooperation and Development (OECD) as "the pursuit of economic growth and development while preventing environmental degradation… and unsustainable natural resource use." Accessed at: http://www.oecd.org/greengrowth/green-growth-indicators/.

[9] Statistics Canada, "Human Activity and the Environment: Agriculture in Canada, 2014," pg. 19. Accessed at: https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2014000-eng.htm.

dependable agricultural land, while the Central Region in Ontario and Quebec has about 20% of agricultural land with the rest in pockets, particularly in British Columbia and Atlantic Canada.[10]

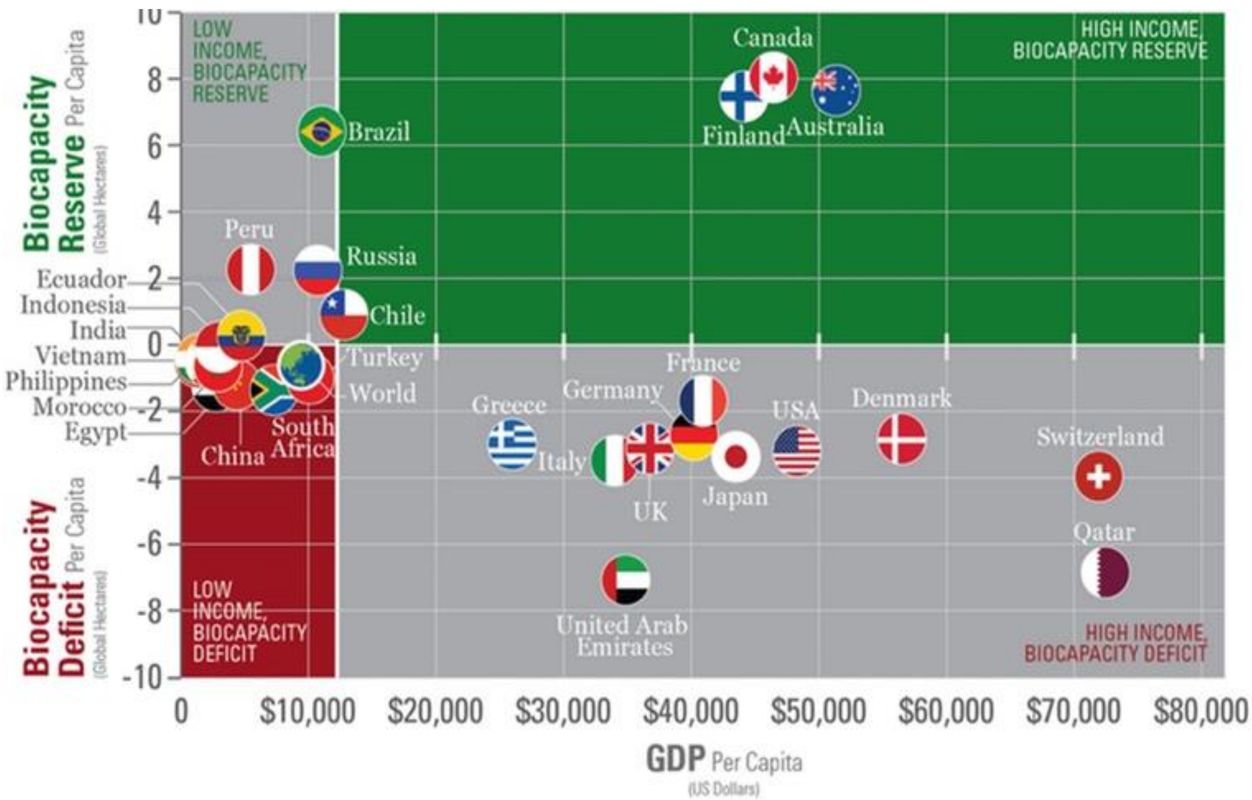
Figure 2: Agricultural Land in Canada, AAFC, 2016[11]



This abundance of natural resources gives Canada a major comparative advantage as a global agricultural producer. Overall, Canada is privileged to be one of a very few countries with high income *and* high biocapacity reserve, along with Finland and Australia (Figure 3).[12] Countries with a high "biocapacity reserve" generally have the natural resource base and ecological assets to exceed their citizens' "ecological footprint" (consumption). As a result, they are, if they take measures to sustain them, able to export their resources without liquidating their national ecological assets or emitting carbon dioxide waste into the atmosphere.

[10] Ibid, pg. 27.
[11] AAFC, Agri-Environmental Indicators Report # 4, "Environmental Sustainability of Canadian Agriculture," 2016, pg. 17.
[12] Global Footprint Network. Accessed at: https://data.footprintnetwork.org/#/.

Figure 3: Biological Reserves/Deficits by Country[13]



With a stable share of just under 7% GDP over the last ten years, the Agriculture and Agri-Food System is a significant contributor to Canadian GDP (Figure 4).[14] It employs approximately 2 million Canadians. The Food and Beverage Processing sector's share of total manufacturing GDP, at 16.4%, makes it the largest manufacturing industry in Canada. While the Primary Agriculture sector may only represent about 2% of Canadian GDP, it has an important role to play in clean growth and sustainability.

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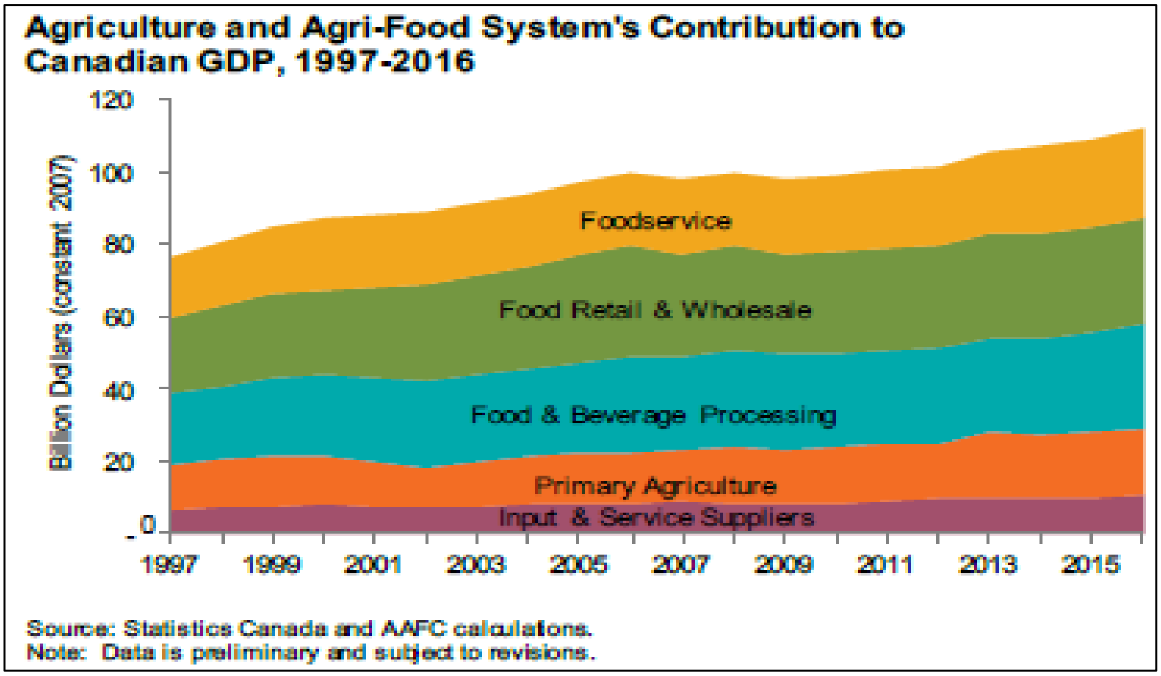
[13] Global Footprint Network, Living Planet Report, "Risk and Resilience in a New Era," 2016. Accessed at: https://www.footprintnetwork.org/content/documents/2016_Living_Planet_Report_Lo.pdf.

[14] The AAFS includes farm input suppliers, primary agriculture, food and beverage processing, food wholesale and retailing and food service, which is a broader definition than that used by Barton in his agri-food analysis (primary agriculture and food, beverage and seafood processing only). Source: Agriculture and Agri-food Canada (AAFC),"An Overview of the Agriculture and Agri-food System, 2017." Accessed at: http://www.agr.gc.ca/eng/about-us/publications/economic-publications/an-overview-of-the-canadian-agriculture-and-agri-food-system-2017/?id=1510326669269.

Figure 4: Agriculture and Agri-Food's Contribution to Canadian GDP[15]



In Response to Barton: The Need for Quality Growth in Agriculture

In response to the fall in oil prices, a weakening economy, and the subsequent threat to Canada's growth rate and standard of living, Finance Minister Bill Morneau set up the Advisory Council on Economic Growth (ACEG), headed by Dominic Barton, to provide advice, which was given through the report *Unleashing the Growth Potential of Key Sectors*."[16] The Barton Report recommended that the government, in concert with the private sector, take a focused approach to removing growth obstacles – thereby unleashing the significant potential of key sectors, one of which was identified as the agriculture and agri-food sector. Moreover, the report recommended "Launch[ing] an agri-food pilot by convening private and public sector stakeholders, identifying major obstacles to growth, setting an aspiration (a vision and quantified goals), and recommending concrete actions."[17]

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[15] AAFC, "An Overview," 2017.

[16] Advisory Council on Economic Growth (ACEG), "Unleashing the Growth Potential of Key Sectors," February 6, 2017. Accessed at: https://www.budget.gc.ca/aceg-ccce/pdf/key-sectors-secteurs-cles-eng.pdf.

[17] Ibid, pg. 3.

The Barton Report established some ambitious growth targets for the Canadian agri-food sector, including an $11 B increase in agriculture exports, and a $19 B increase in processed food exports between now and 2025.[18] Producers, their associations and AAFC are confident that the Barton growth targets for the sector can be achieved.[19] However, because of the strong linkages between agricultural production and the environment, and the implications for Canada's future natural capital and climate change, Barton's growth targets can only be achieved with sustainability in mind.

A Closer Look at the Environmental Performance of Canadian Agriculture

Water

Canada has 7% of the world's renewable water supply, which makes it the third largest renewable freshwater supplier in the world.[20] On a per capita basis, it has the second largest amount of water among developed countries. Nevertheless, water is one of Canada's natural resources that faces pressure from urbanization and agriculture. Some regions in Canada face water scarcity, particularly along the southern border and in densely populated areas. Nearly 20% of monitored water sites register marginal or poor water quality, due to nutrient pollution from agricultural run-off (ie fertilizer and manure) and urban wastewater sources, persistent toxic substances and chemicals (ie pesticides and herbicides). Lake Erie and Lake Winnipeg, for example, which are both quite shallow, suffer increasingly from eutrophication and water pollution issues.[21]

Fertilizer use has increased more than twice as fast as agricultural production since 2000. Areas of highly concentrated agricultural production have led to increased nutrient run-off into waters such as the Great Lakes, Lake Winnipeg and the St. Lawrence River basin. Phosphorous run-off from livestock (dairy) production has also contributed to a decline in water quality in Canada since 1981, particularly in Ontario and Quebec.[22]

Despite the fact that Canada uses a significant amount less nitrogen compared to most other countries, indicators of water quality have worsened over time as measured by the risk of nitrogen contamination (Figure 5). The risk of nitrogen-related water contamination is high for 7% of farmland in Canada. However, by province, the risk of nitrogen-related water contamination is particularly high in Ontario at 41% of farmland, and Quebec, at 75%.[23]

In terms of pesticide use, Canada ranked below many of its counterparts as measured by pesticide use per unit of agricultural land, using far less than Japan, the Netherlands and other European countries. Nevertheless, the risk that pesticides contaminate groundwater has

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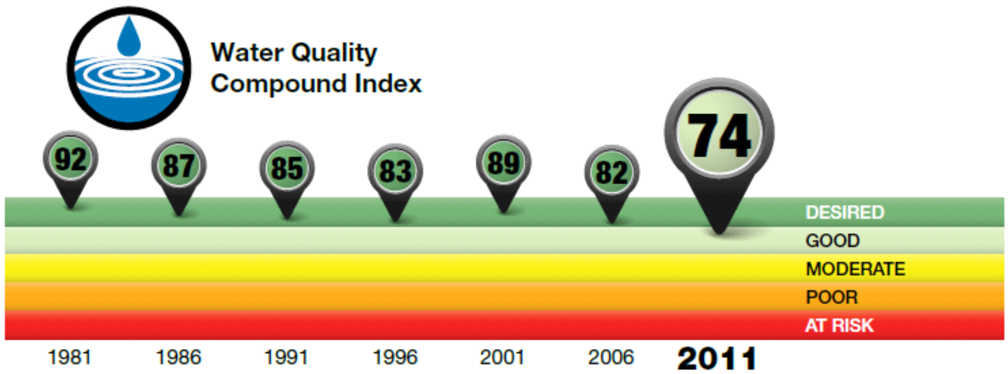
[18] Ibid, pg. 13.
[19] CAPI, "What We Heard, Barton Forward: Optimizing Growth in the Canadian Agri-food Sector," 2018, pg. 2.
[20] Statistics Canada, "Human Activity and the Environment: Freshwater in Canada," Catalog 16-201-X, 2017.
[21] AAFC, Agri-Environmental Indicators Report # 4, 2016, pg. 132.
[22] Ibid, pg. 132.
[23] Ibid, pg. 117.

increased which is contributing to Canada's water quality deteriorating since 1981. This is primarily due to urbanization and agricultural production, which has had consequences for both biodiversity (fish and wildlife) and human recreational activities in Canada.

Figure 5: Water Quality Compound Index, 2011[24]



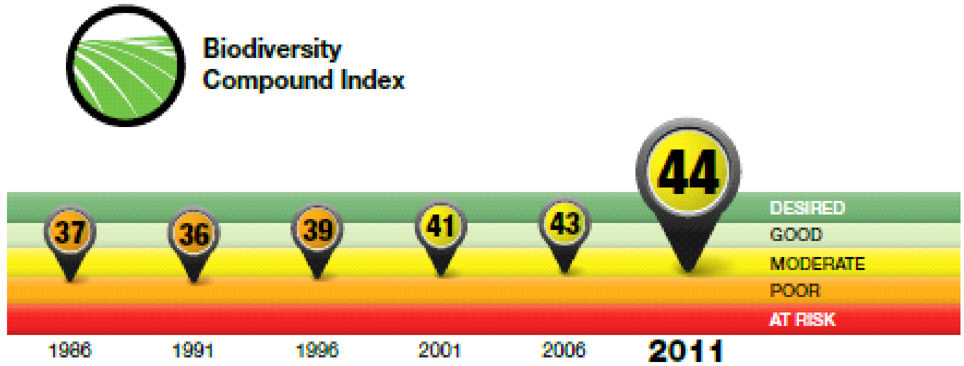
Biodiversity

As global agricultural production expands, areas of mature forests are projected to shrink by 13%.[25] Land use changes, including deforestation, conversion to large monoculture crop areas and increased pesticide use, are major culprits in the loss of biodiversity globally. Polluted streams and waterbodies also contribute. According to the OECD, about one-third of biodiversity in rivers and lakes worldwide has already been lost. [26] The insect population, which is another indicator of biodiversity health, is globally in decline. The World Wildlife Fund (WWF) estimated that populations of invertebrates declined by about one third between 1970 and 2008.[27]

Biodiversity in Canada, as measured by AAFC's agri-environmental indicators, has improved only marginally over the past decade (Figure 6). This indicator is a combination of soil cover and wildlife habitat indexes. The marginal improvement was primarily the result of improved soil cover, due to more conservation till, less summerfallow and improved farm management practices. On the other hand, the wildlife component of this indicator showed a significant decline since 1996. By 2011, the state of wildlife habitat capacity on farmland in Canada was poor, with 14% of farmland reporting major declines. This was due to the loss of natural and semi-natural land and the intensification of farming. In Eastern Canada, in particular, the loss of perennial hay and pasture habitat was a major contributor to this decline.[28]

[24] Ibid, pg. 118.
[25] Food and Agriculture Organization of the United Nations (FAO), "The Future of Food and Agriculture," 2017.
[26] OECD, "Environmental Outlook to 2050," 2015. Accessed at: http://www.oecd.org/env/indicators-modelling-outlooks/49846090.pdf.
[27] WWF, The Living Planet Report, "Biodiversity, Biocapacity and Better Choices," 2012. Accessed at: http://d2akrl9rvxl3z3.cloudfront.net/downloads/lpr_2012_1.pdf
[28] AAFC, Agri-Environmental Indicators Report # 4, 2016. "Biodiversity Compound Index", pg.2. Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/environmental-sustainability-of-canadian-agriculture-agri-environmental-indicator-report-series-report-4/?id=1467307820931

Figure 6: Biodiversity Compound Index, 2011[29]



In its recent report on Canada, the WWF reported that half of our monitored species are in decline, with an average decline of 83% over the 1970 to 2014 period.[30] Some wildlife groups have experienced larger declines than others: 54% of mammals, 51% of fish, 48% of birds and 50% of amphibians and reptiles have experienced declining populations since 1970. For species at risk (SAR) in Canada, in particular, populations declined by 43% between 1970 and 2002, and after legislation was introduced in 2002, populations declined by 28% (between 2002 and 2014). While some measures introduced, such as tight restrictions on dangerous chemicals, like DDT, limits on fishing and hunting, and restored wetlands, there are still measures that are needed to prevent further declines. Agricultural producers can play a role through adopting Best Management Practices (BMPs), while government and voluntary sector initiatives (eg. ALUS) can also help protect wildlife habitat[31].

Air Quality

Compared with many OECD countries, Canada generally has good air quality. Recently, outdoor air quality regulations have been strengthened and emissions standards established. According to AAFC indicators, agriculture's negative impact on air quality has been reduced significantly since 1996, primarily due to reduced fine particulate matter (PM2.5) in the air and stable GHG emissions (Figure 7). However, about 30% of Canadians live in areas where outdoor levels of PM2.5 and/or ozone exceed national air quality standards. This is found mostly in cities in Ontario and Quebec.

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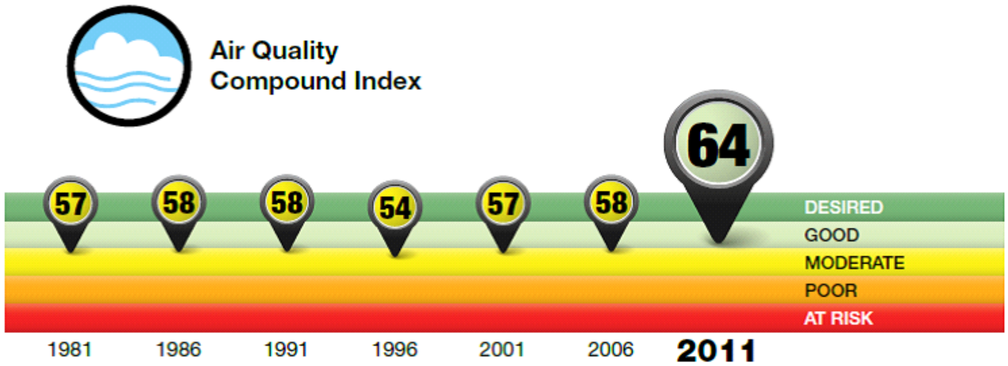
[29] Ibid.

[30] WWF, The Living Planet Report Canada, "A National Look at Wildlife Loss," 2017. Accessed at: https://assets.wwf.ca/downloads/WEB_WWF_REPORT.pdf.

[31] See Annex B for a description of the ALUS initiative.

Figure 7: Air Quality Compound Index, 2011[32]



Soil Health

Soils are the foundation of agricultural production and require adequate soil organic carbon (SOC) and a healthy microbiome to remain productive. Soils also play a very important role in both contributing to and mitigating climate change. In Canada, during the late 1800s and early 1900s, the conversion of native grasslands to croplands on the Prairies, and the loss of the native grazing bison herd, caused a depletion of as much as 60% of the SOC in the first meter of the soil profile.[33] These losses of carbon and other nutrients were exacerbated by poor management practices, severe wind erosion and a period of extremely dry climate, which led to the abandonment of over 3 million ha of cultivated prairie land between 1930 and 1938. As native vegetation returned on these lands, soil carbon levels rose, with full restoration occurring over the last 70 years. BMPs, such as conservation tillage, crop rotation, rotational grazing, cover crops, and the sowing of perennial grasses on native grassland have all contributed to the restoration of lost soil carbon.[34] This has resulted in significant improvement in soil quality over the period 1981-2011 (Figure 8).

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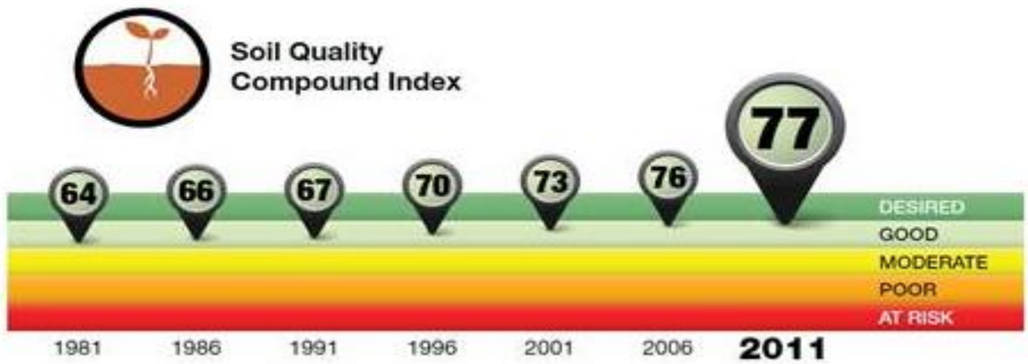
[32] AAFC, Agri-Environmental Indicators Report # 4, 2016, pg. 5.
[33] S. Bohm-Woods, "Agricultural Soils as a Solution Provider to Climate Change," for CAPI, October 2018, pg. 6. Accessed at: https://capi-icpa.ca/wp-content/uploads/2018/10/2018-1012-CAPI-paper-AG-SOILS-SOLUTION-PROVIDER-CLIMATE-CHANGE.pdf.
[34] AAFC, Agri-Environmental Indicators Report # 4, 2016, pg. 82.

Figure 8: Soil Quality Compound Index, 2011[35]



While the overall soil quality in Canada has improved, national averages mask significant regional differences. For example, 56% of cropland in Ontario and 80% of cropland in Quebec are experiencing large decreases in SOC. On the other hand, 79% of cropland in Saskatchewan experienced a large increase in SOC. This is largely due to differences in agro-climatic conditions, as the Prairie region has soil and climate that is more amenable to reduced-till and no-till practices, while in Central Canada, the soil type and moisture conditions are less amenable to these practices.[36]

A recent analysis by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) estimated that 82% of Ontario's agricultural soils are net carbon emitters, 68% of Ontario's farmland is in an unsustainable erosion risk category, and 53% of Ontario's cropland has low or very low soil cover.[37] However, the improvement on the Prairies far exceeds these declines, resulting in improved soil quality in Canada overall. Between 1981 and 2011, soil organic carbon in Prairie soils rose from 9 kg/ha/yr to 97 kg/ha/yr. Regarding risk of soil erosion, Alberta, Saskatchewan and Manitoba reported 87%, 78% and 67% of cropland with very low risk of soil erosion, compared to 32% of farmland in Ontario and 77% in Quebec. [38]

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[35] Ibid, pg. 3.
[36] S. Bohm-Woods, Agricultural Soils, pg. 8.
[37] OMAFRA, "New Horizons-Ontario's Soil Health and Conservation Strategy," April 2018, pg. 12. Accessed at: http://www.omafra.gov.on.ca/english/landuse/soilhealth.htm.
[38] AAFC, Agri-Environmental Indicators Report # 4,2016. "Soil Erosion Indicator". pg. 85 Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/environmental-sustainability-of-canadian-agriculture-agri-environmental-indicator-report-series-report-4/?id=1467307820931

Greenhouse Gas Emissions

Relative to global GHG emissions, Canada is the fourth largest emitter of GHGs and the second most energy and carbon intensive economy in the OECD.[39] However, many international comparisons are presented on a per capita basis, which is not a particularly fair comparison, given that Canada exports a large share of its production, to be consumed in other countries. In fact, a more appropriate indicator would be measured by GHG emissions per unit of land or output basis, i.e. GHG intensity.

GHG emissions from agriculture accounted for approximately 10% of Canada's total GHG emissions in 2016, according to the National Inventory.[40] GHG emissions in agriculture originate from four sources:

- **Direct emissions:** from nitrous oxide (N_2O) from fertilizer applications and methane (CH_4) from animal production and rice cultivation;
- **Activities that release soil carbon reserves:** from tillage, mono-cropping, and deforestation;
- **Carbon dioxide (CO_2) emissions:** from fossil fuel used by farm equipment, heating barns and drying grain; and
- **Indirect CO_2 emissions:** arising from fossil fuel use in the production of agricultural inputs such as pesticides or fertilizer.

Slightly more than 50% of agricultural emissions arise from livestock production and manure management, with the remainder coming from cultivation of agricultural soils, and nitrogen fertilizer use.[41] While the contribution of agriculture to Canadian GHG emissions is relatively small, its contribution to national CH_4 emissions is quite large, at 27% of the total. The sector also accounts for a relatively large share of N_2O emissions, at 70%.[42] Approximately 15 % of agricultural GHG emissions come from on-farm use of fossil fuels for farm machinery, heating barns and grain drying.[43]

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[39] OECD, "Environmental Performance Review: Canada," 2017. Accessed at: http://www.oecd.org/environment/country-reviews/Highlights_OECD_Environmental_Performance_Review_Canada2017.pdf.

[40] ECCC, National Inventory Report on Greenhouse Gas Sources and Sinks in Canada, 1990-2016. Accessed at: http://publications.gc.ca/collections/collection_2018/eccc/En81-4-2016-3-eng.pdf.

[41] Prairie Climate Centre, 2018. http://prairieclimatecentre.ca/.

[42] Mitigation Working Group Report, 2016. Accessed at: https://www.canada.ca/content/dam/eccc/migration/cc/content/6/4/7/64778dd5-e2d9-4930-be59-d6db7db5cbc0/wg_report_specific_mitigation_opportunities_en_v04.pdf

[43] Direct emissions from agricultural processes, excluding combustion of fossil fuels account for 8.5% of total emissions, or 60 Mt CO2-e in 2016. ECCC, National Inventory of Emissions, 2018.

The Way Forward

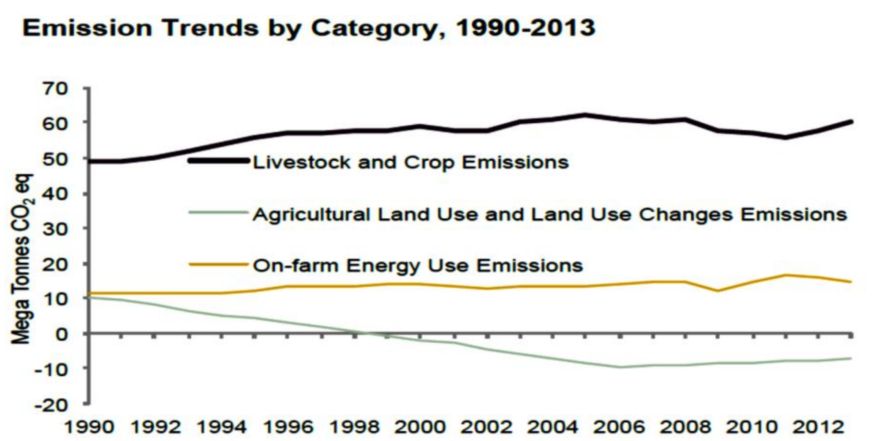
Clean Growth in Agriculture

One of the challenges for advancing the agenda for Clean Growth in Agriculture is determining the targets to be achieved. It would be exceptional if all the pillars of Clean Growth in Agriculture—increases in productivity; increases in quality of water, biodiversity, air, and soil; and decreases in greenhouse gas emissions—could be advanced simultaneously. This is however rarely the case and trade-offs are necessary.

If one focuses on achieving the dual goals of productivity gains and GHG emission reductions in agriculture, statistics show that the value of Canadian agricultural production is doing relatively well on a per unit of output basis. Agriculture and food production has more than doubled since 2007,[44] while GHG emissions from agricultural activity remained relatively stable (Figure 9), resulting in a decline in GHG emissions per unit of output. As well, in absolute terms, GHG emissions from land use change have declined significantly, while those from on-farm energy use have been stable, and from crop and livestock production, have increased slightly.

These changes are due to the introduction of various Beneficial Management Practices (BMPs), new technologies and innovations and policies to encourage them. Examples include zero/reduced till cultivation, the use of cover crops, improved animal genetics and feeding efficiency and the more recent introduction of the 4R fertilizer stewardship program.[45]

Figure 9: Emission Trends by Category, 1990-2013



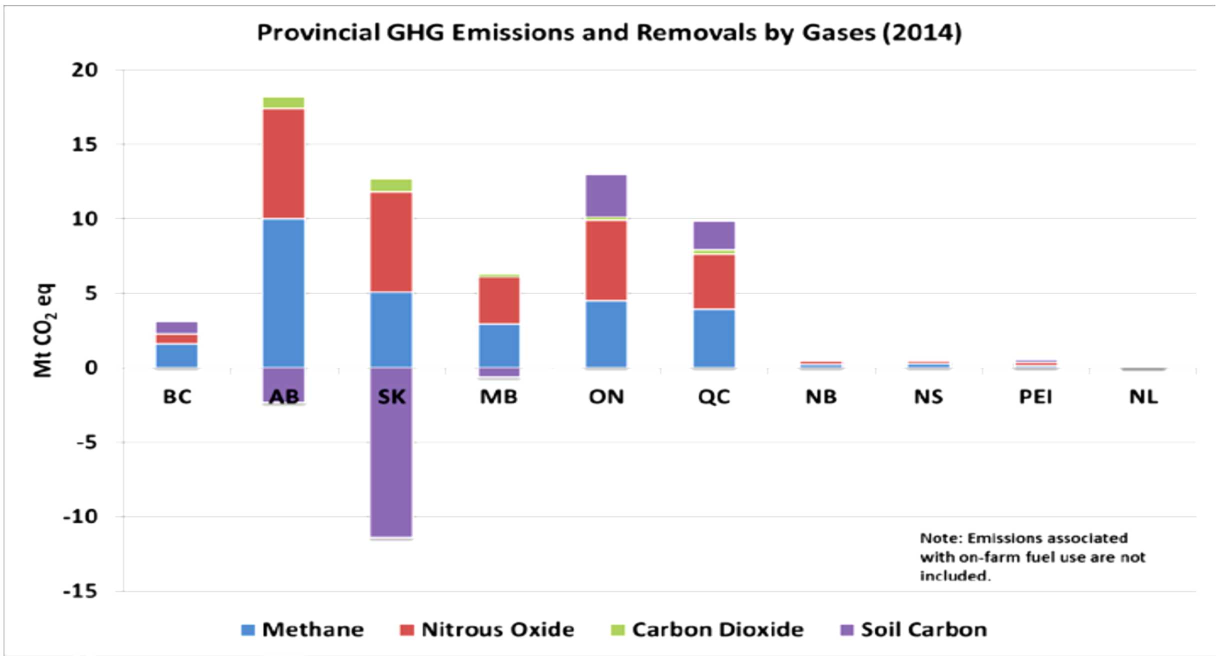
Source: Environment Canada, National Inventory Report 2015 and Natural Resources Canada, National Energy Database, 1990-2012..

[44] Measured by GDP growth in constant 2007 dollars. See AAFC, Medium Term Outlook for Canadian Agriculture, 2017. Accessed at: http://www.agr.gc.ca/eng/about-us/publications/economic-publications/2018-medium-term-outlook-for-canadian-agriculture/?id=1536863615431.

[45] This program, introduced and promoted by the Fertilizer Institute, and in Canada by Fertilizer Canada, provides information and training as well as certification on the optimal application of manure and fertilizers to ensure the right source, the right rate, the right time and the right place for sustainable and profitable agricultural production. Accessed at: http://www.nutrientstewardship.com/.

However, much like soil health, differences in the sources of GHG emissions vary greatly by province and not all provinces are achieving the same efficiencies. This situation reflects the various agronomic conditions, product mixes, and the relative size of the agriculture sector in each province (Figure 10).

Figure 10: Agriculture CO2e sinks and sources by province[46]

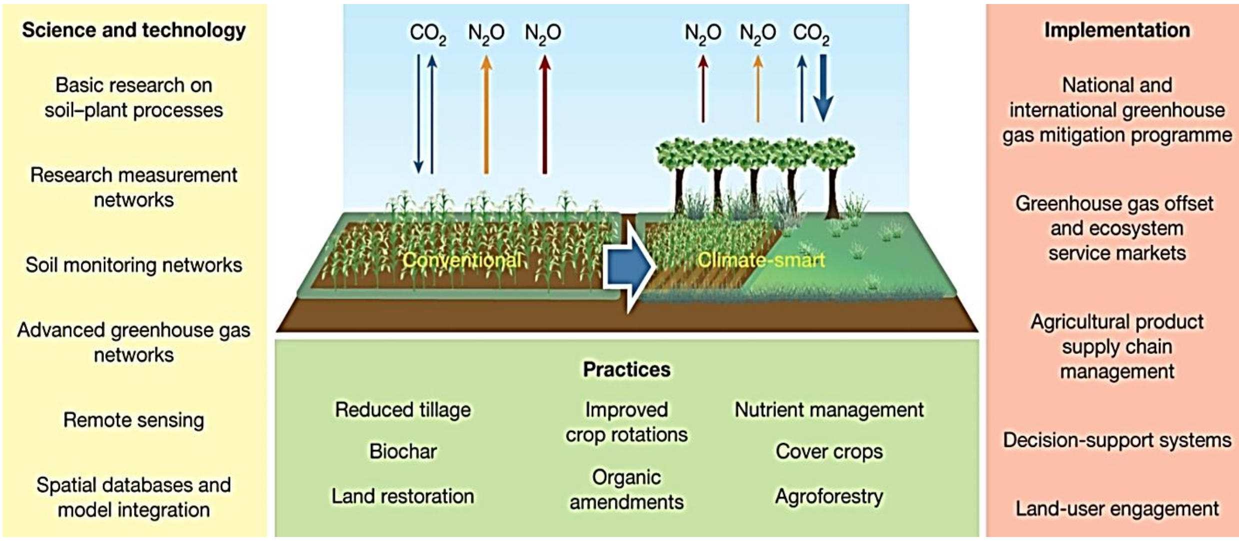


Canadian agriculture, as a whole, has steadily reduced its GHG emissions intensity as a result of dramatic disruptive technological changes. The efforts by governments, industry and academia continue to enable the industry to reduce its emissions. The right combination of programs, incentives and policies could accelerate this transition towards becoming a net sink and providing solutions for the rest of the economy.

Reducing GHG emissions while maintaining or improving productivity is central to a Clean Growth in Agriculture strategy, although it focuses on only one environmental concern arising from agriculture. Reducing GHG emissions is complex as the following chart shows (Figure 11). Clean Growth in Agriculture relies on innovations in three key areas: science and technology, practices and implementation.

[46] ECCC, Mitigation Working Group Report, 2016.

Figure 11: Components of Clean Growth in Agriculture[47]



The next steps are not only about developing and adopting the technologies and practices that could move the sector towards carbon neutrality, but also about national and international GHG mitigation programmes, ecosystem service markets, supply chain certifying, labelling, and monetizing products at prices that covers the cost of carbon neutrality.

Policy Initiatives by Government

In terms of government policies and initiatives, options consist of regulations, economic instruments, moral suasion, and education. Canada's strong commitment to climate change mitigation and environmental improvement was made clear with the development of its *Pan-Canadian Framework on Clean Growth and Climate* strategy.[48] This was an agreement signed between federal, provincial and territorial governments in 2016 which provides an overarching framework for clean growth. This, together with Canada's commitments to the *UN Sustainable Development Goals,* signals that Canada is on the right road to future environmental, social and economic sustainability.[49] The federal government makes use of several policy initiatives to advance its sustainability goals in agriculture (Figure 12).[50]

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[47] K. Paustian et al, Nature 532, 2016, 49–57. Accessed at : https://www.nature.com/articles/nature17174.
[48] Pan Canadian Framework on Clean Growth and Climate Change, November 2016. Accessed at: https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html
[49] "Canada and the 2030 Sustainable development goals," Pg. 3. Accessed at: https://international.gc.ca/world-monde/issues_development-enjeux_developpement/priorities-priorites/agenda-programme.aspx?lang=eng.
[50] Each of these initiatives is explored in greater detail in Annex A in the Full Report.

Figure 12: Federal and Provincial Government and Voluntary and Industry Initiatives

GOVERNMENT	VOLUNTARY/INDUSTRY
National Environmental Farm Plans (EFPs)	Alternative Land Use Systems Canada (ALUS)
Agroecosystem Living Labs Approach (ALL)	Canadian Roundtable for Sustainable Crops (CRSC)
Beneficial Management Practices	Canadian Roundtable for Sustainable Beef (CRSB)
Ontario's Agricultural Soil Health and Conservation Strategy	4R Nutrient Stewardship
Alberta's On-Farm Stewardship (OFS) and Confined Feeding Operations (CFO)	Natural Capital Coalition
Alberta's Agricultural Carbon Offsets Program	Nature Conservancy of Canada; Ducks Unlimited Canada (DUC)

However, the high cost of implementing and enforcing environmental regulations for agricultural producers often makes the effectiveness and desirability of these measures questionable. Economic instruments, such as taxes imposed on undesirable actions or subsidies to encourage desirable actions, target only actions and therefore cannot always guarantee outcomes. For example, the EU's experience with green subsidies to farmers for environmental practices, demonstrates this weakness.[51] In addition, the application of taxes and economic tools generally remain at the will of political governments. The examples of taxes in the U.S., Australia, and various Canadian provinces make clear the frailness of this and suggest that market-based solutions might be better instruments of choice for incenting farmers to improve environmental outcomes.

Innovative Practices by Industry

Agricultural producers know that in order to ensure the long-term sustainability and profitability of their land, they need to be good stewards. By adopting BMPs to increase soil organic matter, optimize nitrogen and pesticide use, minimize GHG emissions, reduce manure, pesticide and fertilizer run-off and prevent soil erosion, producers can do their part. However, this requires knowledge and awareness, and investments in innovations and new technologies. There are,

[51] See Annex C in Full Report for a description of the EU Green Programs and their effects.

however, costs involved and foregone revenues. And while producers can benefit from these actions themselves, society also benefits. Producers are not necessarily rewarded through the marketplace, since the environmental benefits are not monetized for producers through market prices. Thus, in addition to government policy interventions, voluntary actions and industry-led initiatives will be needed to mitigate the environmental impacts of agriculture while ensuring long term growth and prosperity, or in short to ensure "clean growth". Community-based actions and initiatives can promote voluntary changes in practices through motivating and enabling practitioners on the ground. However, these initiatives will only work if the information is available and shared in an open platform and the required changes do not create an economic loss for the producers. Figure 12 provides examples of some of these community-based voluntary initiatives that have been introduced to promote BMPs and clean growth.[52]

Finally, investments in Research and Development (R&D), innovation, new technologies and the commercialization and adoption of these new technologies will be required to ensure clean growth in agriculture. Amongst the various emerging technologies that are being seen as promising for agriculture, include precision agriculture, robotics, artificial intelligence, drones as well as new developments in soil microbiomes. In addition, research on high yielding plant breeds with carbon deposition and storage characteristics, and grass and grazing systems that improve efficiencies, all hold significant promise. These are described in more detail in the Full Report. However, two areas of innovative developments and practices that if implemented and widely adopted, could further lead to sustainable growth are described below. Like all emerging technologies and practices, they may however, need to be appropriately incentivized, which will require investments, new programs and other mechanisms.

Biological carbon sequestration

While agricultural production can yield substantial GHG emissions, it can also capture carbon from the atmosphere. Plants can remove carbon from the atmosphere and contribute a portion of that carbon to stable pools in the soil. Once crops mature and are harvested, much of the carbon captured in them is removed from the field, but the rest that is in the root system and in the residual plant material serves as carbon feedstock for ingestion by the microbial community that transforms it to soil organic carbon (SOC).[53] Carbon sequestration, then, is an important means by which Canadian agriculture producers could contribute to Climate Change mitigation. Since about 2000, agricultural lands have become a net sink for CO2 when land use changes are considered.[54] This is particularly important for livestock producers who manage pastures and grazing lands where carbon can be stored. Research shows that by increasing soil carbon

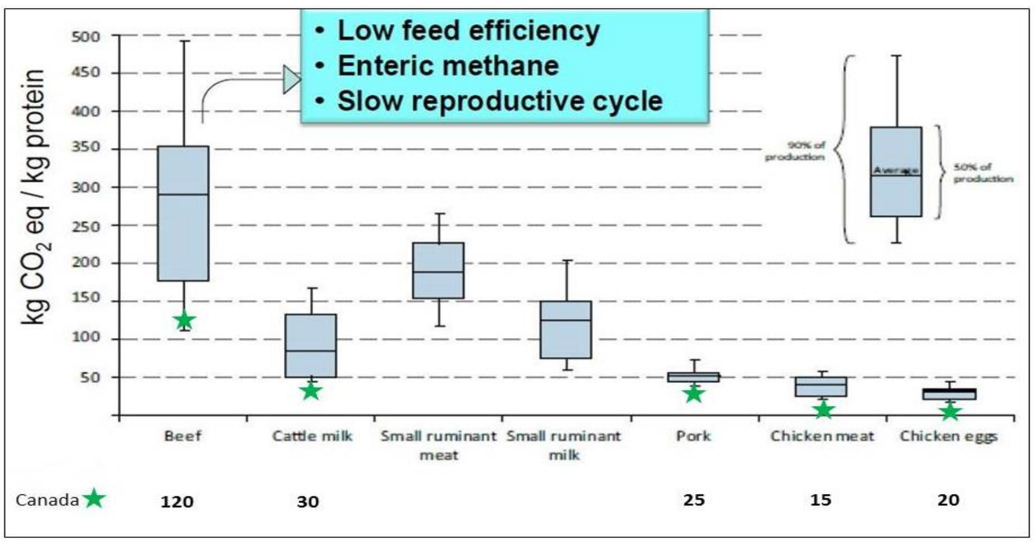
[52] Each is explored in the Full Report.
[53] Bohm, Susan-Wood, "Agricultural Soils as a Solution Provider to Climate Change," pg. 5.
[54] AAFC, Science and Technology Branch," Measuring Greenhouse Gases." Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/climate-change-and-agriculture/greenhouse-gases/measuring-emissions/?id=1329321977257/.

sequestration in Canadian soils by 0.4% per year, the agriculture sector could offset its entire annual agriculture sector emissions.[55]

Improved animal husbandry and animal genetics

Much effort is being made to reduce GHG emissions from livestock production. Dramatic gains have been made in reducing GHG emissions intensity in the cattle sector in Canada between 1981 and 2011.[56] As a result of improved reproductive efficiency, reduced time to slaughter, increased crop yields, and a shift towards high-grain diets that enabled cattle to be marketed at an earlier age, GHG intensity fell by 14% between 1981 and 2011 in Canada (Figure 13). This makes Canada one of the most GHG efficient producers of animal protein in the world at 12 kg CO_2 equivalent per kg of live weight, less than half the world average.[57] As a result, CH_4 and N_2O emissions from livestock production are some of the lowest in the world, in North America compared with other regions (Figure 14).

Figure 13: GHG Emissions Intensity of Canadian Livestock[58]



The fact that Canada has one of the lowest GHG emissions intensity for livestock in the OECD countries suggests that Canada has a comparative advantage and could produce environmentally sustainable beef for export to high quality markets. This could be a salient component of an agri-food growth strategy but requires these properties to be certified and branded to monetize the benefits to society.

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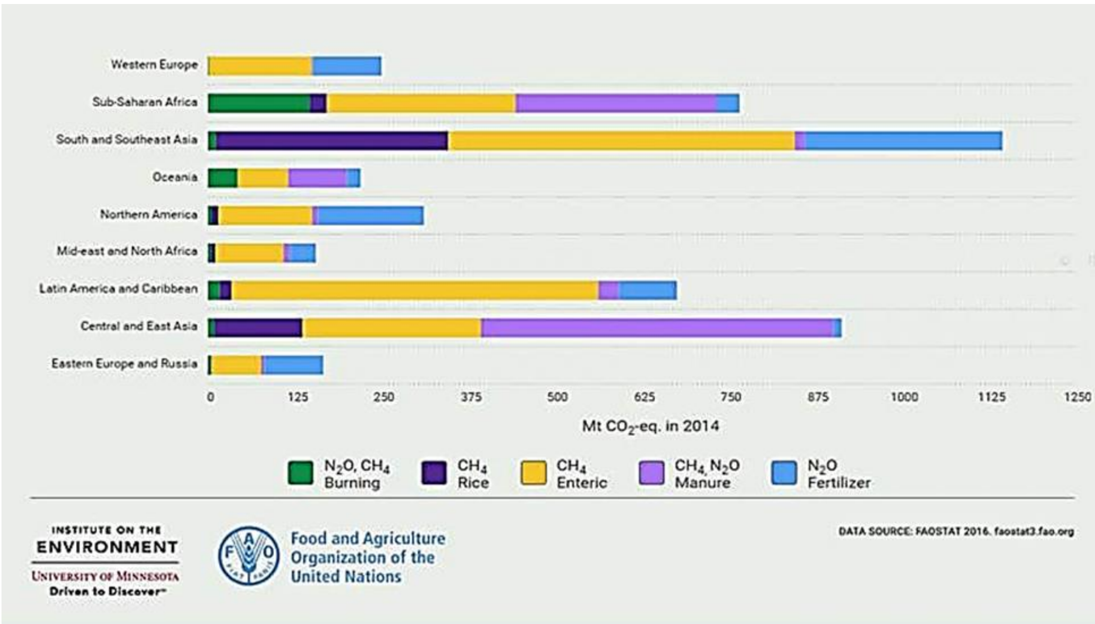
[55] Janzen and McConkey, "Measuring Change in Soil Organic Carbon Storage," March 2016.
[56] G. Legesse, et al, "Greenhouse gas emissions of Canadian beef production in 1981 as compared with 2011," Anim. Prod. Sci. 56, 2016, pg. 153-168. Accessed at: http://dx.doi.org/10.1071/AN15386.
[57] Canadian Cattlemen's Association, "Beef Industry Strategies for Reducing Greenhouse Gases and Building the Green Economy," Accessed at: http://www.cattle.ca/assets/0c1041cd87/Strategies-for-Reducing-Greenhouse-Gases-from-Beef-Production-in-Canada-26.07.16.pdf.
[58] FAO, GLEAM and AAFC estimates.

Figure 14: GHG Emissions from Livestock Production, by Region, 2015



Investments to Target Clean Growth in Agriculture

Implementation of new technologies and practices will require a major overhaul in national and international policies and approaches to create enough incentives for them to be adopted at a scale that could maintain the ability of the sector to produce while contributing to climate change mitigation. This is where the real challenge lies: to be able to increase agricultural production while reducing sectoral GHG emissions.

Investments by both the public and private sectors could go some real distance to encouraging positive action in this direction. Five immediate action areas would be assisted by increased investment.

(1) Investment in policy initiatives in the agriculture and food production space to prioritize target areas for environmental improvement

This Executive Report demonstrates that agriculture and food production impacts at least five distinct areas of environmental outcomes—those affecting water, biodiversity, air quality, soil health and greenhouse gas emissions. As a recent CAPI dialogue revealed,[59] it is rare that the

[59] "Optimizing Land Use for Sustainable Growth: a CAPI Dialogue," Calgary, February 21-22, 2019. Available at: https://capi-icpa.ca/events/optimizing-land-use-for-sustainable-growth-a-capi-dialogue-february-21-22-2019/

agriculture-environment dialogue yields clearly articulated priorities for outcomes. Is one to prioritize those which are most important to the planet and to Canada, or those which are most achievable and are most likely to be taken up by agriculture and food producers in Canada? Too often experts, practitioners or even the general public speak only in general terms of improving agriculture's environmental performance.

Investments that specifically encourage dialogue are needed for establishing consensus around the environmental outcomes and targets that require strategic effort and focus. GHG emissions are, of course, a first priority. However, how much focus should be placed on other positive environmental outcomes, that can be achieved more easily or at the lowest cost? This dialogue needs to happen to bring focus to the direction that must be taken to enhance the provision of positive environmental goods and services from agriculture

(2) Investment in technological advances and implementation of beneficial management practices that yield improved environmental outcomes for specific environmental goals

Where it has been determined that one of the environmental outcomes should be advanced above others in agriculture and food production, then new investment in existing or new technologies facilitating BMPs could assist either in the development of the BMP or its scale-up.

The most obvious example of this is in the scale-up of 4R fertilizer technology and techniques. 4R fertilizer technology not only improves profitability for farmers because they can apply less fertilizer to their crops while maintaining or even enhancing yields, but also leads to less nutrient loss to ground water, preventing water quality deterioration, and less loss to the air, preventing climate change. Studies show however, that the uptake of this technology with "win-win" benefits has had a relatively slow scale-up amongst Canadian producers. In 2014, there were 500,000 acres under 4R Nutrient Stewardship, and this rose to only 2.2 million acres by 2016. With Fertilizer Canada's goal of 20 million acres to be covered by 2020, there is still a lot of work to do. Research shows that by applying the 4Rs to corn production in Ontario for example, can reduce GHG emissions by an average of 50%, reduce phosphorous losses through run-off by 60%, and increase yields by nearly 20%. Currently, only 68% of farmers in Ontario use some form of 4Rs. By raising adoption rates to 75%, there could be a reduction of GHGs by 540 kg CO2Eq/ha/yr.[60] With 2.2 million ha of Ontario cropland in corn, this translates into an additional 61,600 ha covered by 4Rs and an additional .03 Mt of CO2eq emission reductions.

Other examples of new technologies that could reap large environmental benefits or significantly reduce GHG emissions through widespread adoption and scale-up, include precision agriculture, new crop varieties that sequester carbon, better crop rotation and more cover crops and no-till. For example, by adding pulses into the crop rotation (oilseed-pulse-durum wheat) on the Prairies,

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[60] Fertilizer Canada, "Key Findings of the Canadian 4R Research Network", 2018. Accessed at: https://fertilizercanada-ksiu6qbsd.netdna-ssl.com/wp-content/uploads/2018/08/fc_4R-key-findings2018_en_vf-digital.pdf

was found to reduce the carbon footprint of cropping by 29%, relative to a non-pulse crop rotation (ie. cereal-cereal-durum wheat). How this can be changed for better economic and environmental results is a question well worth asking.[61]

(3) Investment in technological advances and implementation of beneficial management practices that yield improved environmental outcomes for different regions of agricultural production

Where it has been determined that a specific region of Canada should be targeted for improved environmental outcomes for regional agriculture and food production, then new investment for producers or their associations could be negotiated to improve the general uptake of BMPs or nascent technology that advance environmental outcomes in the region.

For example, an important environmental concern in Prairie agriculture are PM2.5 emissions and the human health concerns they raise while in Central Canadian agriculture GHG emissions or water quality are bigger concerns. Stakeholders targeting these regional priorities could well engage local, provincial and federal governments for policy innovation, while also engaging producer associations, producers themselves and non-governmental organizations to identify and then roll-out through government policy or market incentives, the BMPs or other measures to bring about behavioural changes to advance the desired environmental outcomes in the region.

(4) Investment in scaling-up of known technologies that will yield positive environmental outcomes

Similar to (2) above, stakeholders may have already identified a technology or project that they feel will yield a particular environmental benefit as it relates to the field of agriculture and food production.

An example might be an organization's goal of reducing GHG emissions by the reduction of the use of fossil fuels by increasing the efficiency of petroleum engines or the replacement of them by electric engines. This objective, although somewhat narrow in achieving environmental benefits in the agriculture sector, could be championed through investment in the development of power technologies that would be available to the agriculture sector or by assistance in the uptake of such technology by producers.

[61] CAPI-AgWest Bio Workshop, Presentation to Saskatoon Barton Forward "Growth, Innovation and Sustainability for Pulse Crops", December 2017.

(5) Investment in the creation of communities of interest that will generate new and transferable knowledge and build support for increasing agricultural productivity and environmental goods and services ("win-win" communities of advancement)

Perhaps what is needed most in the area are new concepts and constructs of leadership in imagining "win-win", "agriculture-environment", "profitability-sustainability" solutions. What we need is a community of experts and practitioners, a NETWORK of thought leaders, who can come together to link many of the challenges in adopting clean growth, like aligning private and public benefits to boost awareness and the adoption of new technologies, and then presenting suggestions to existing national and international policies and initiatives with sufficient incentives for them to be adopted. Essentially this NETWORK would integrate science and policy research with industry and business practices and provide policy, innovation, and technology suggestions that would be applicable at the micro-level while also creating a real impact on a national and international scale. Other recent initiatives using this model have proven successful for introducing transformative forces for climate change: this includes the Transition Accelerator organization.[62]

In the process towards sustainable growth, quality growth, clean growth in agriculture, three main steps are required:

(1) Stage 1 - Discovery (science, innovation and technology);
(2) Stage 2 - Market Availability (crafting beneficial management practices), and
(3) Stage 3 - Implementation (scalability and widespread adoption). [63]

We believe that this NETWORK can engage in initiatives that focus on a holistic approach to clean growth, awareness and education, and put knowledge gained into practice to encourage sustainable agriculture and growth.

Beyond the traditional dissemination of knowledge, the promotion of new technologies and innovations, and support to farmers and producers will only encourage further collaboration and developments in the goal of clean growth. The focus should be based on optimizing land use in Canada, while maintaining the sector's competitiveness, by bringing a transdisciplinary group of experts together to both help prioritize goals to clean growth in agriculture, as well as identify the investments needed to achieve them. In this way, collaboration between public and private stakeholders, industry, community and voluntary organizations can work towards ensuring the sector can optimize growth for a sustainable future.

[62] This proposed Network is similar to a recently introduced organization called "the Transition Accelerator", which "convenes researchers, industry experts and civil society leaders to envision, chart and pilot game-changing pathways to address climate change that will help Canadians thrive into the 21st century and beyond". Accessed at: https://www.transitionaccelerator.ca/

[63] The Transition Accelerator initiative describes similar steps as part of its process.

2. Full Report

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Glossary of Terms

AAFS: The Agriculture and Agri-food System includes farm input and service suppliers, primary agricultural producers, food and beverage processors, food retailers and wholesalers and foodservice providers.

ACEG: The Advisory Council on Economic Growth develops advice on policy actions and contributes to conditions that enable strong and sustained long-term economic growth.

Biological carbon sequestration: The process of capturing carbon dioxide from the atmosphere and the storage through biological and geological processes and dissolution in oceans to mitigate climate change impacts.

Biomass: Organic matter produced by living or recently living organisms (including products from agriculture) used to produce bio-products.

Bioproducts: Energy derived from renewable biological resources, such as ethanol from corn and biodiesel from canola.

BMPs: Beneficial Management Practices are farming practices designed to minimize the potential negative impact on the environment.

CH4: Methane is a chemical compound, which is a colorless and odorless flammable gas. It is the main constituent of natural gas and is produced by animal agriculture, particularly ruminants, through enteric fermentation and manure.

Clean growth: Economic growth that occurs in a manner which: i) minimizes environmental impacts; ii) uses energy and resources more efficiently; and iii) minimizes GHG emissions.[1]

CO2e: Carbon dioxide equivalent describes different greenhouse gases in a common unit and measures the amount of CO2 that would have the same global warming potential.

Conservation till/no-till: is the practice of directly seeding into crop residue, avoiding any mechanical tillage of the soil.

GHG: Greenhouse Gases are any gas that absorbs infrared radiation and traps heat in the atmosphere. Common examples of greenhouse gases include water vapor, carbon dioxide, nitrous oxide, and ozone.

GHG emission intensity: The measure of the level of greenhouse gas emissions per unit of economic output. It is the emission rate of a given pollutant relative to the intensity of a specific activity.

Global commons: This refers to the earth's unowned natural resources. Examples include the atmosphere, space, and the oceans.

N: Nitrogen is a chemical element, which is a colorless and odorless gas, and forms most of the earth's atmosphere.

Natural capital: A country's natural assets. Examples include land, forests, minerals, or energy reserves.

Negative externalities: When a producer or consumer imposes costs on others for which the imposer cannot be charged

N2O: Nitrous Oxide is a chemical element, which is emitted from the soil during agricultural soil management activities, including fertilizer application and field burning, as well as from manure.

OECD: The Organization for Economic Cooperation and Development is an international organization with the mission of promoting policies to improve the economic and social well-being of people around the world. There are 34 member-countries.

OMAFRA: Ontario Ministry of Agriculture and Food and Rural Affairs

PM2.5: Fine Particulate Matter is a mixture of solid particles and liquid droplets that are suspended in the air and contribute to air pollution.

Positive externalities: When a producer or a consumer creates benefits for others for which the provider cannot receive benefits.

SDGs: Seventeen Sustainable Development Goals (SDGs) were set by the United Nations in 2015. The goals include the reduction of poverty and hunger, improve the health of populations and end environmental degradation, climate change, and waste by 2030.

SOC: Soil Organic Carbon is a measurable component of social organic matter (SOM). It involves cycling of carbon through the soil, vegetation, ocean and the atmosphere.

Soil Profile: measures the characteristics of the soil including its soil organic matter (SOM) carbon, composition and erodibility.

Summerfallow: The formerly widespread practice, primarily on the Prairies, of leaving the soil unseeded and uncultivated for one growing season, in an effort to improve moisture levels.

WEF: The World Economic Forum

UN: An international organization with the goal of increasing international political and economic cooperation.

Introduction

Two major challenges facing the world in the 21st century are climate change and food security. Agriculture sits at the centre of the proverbial "eye of the storm" due to its contribution to greenhouse gas (GHG) emissions and climate change, and the impact climate change will have on agriculture and future food production. Also, there is great potential to reduce net emissions by changing agricultural practices.

The challenge remains whether agricultural production can grow enough to produce nutritious, affordable, and accessible food to meet the demands of an increasing global population, without degrading the environment or depleting the natural resource base or "natural capital" (land, water, air, biodiversity).

In response to this challenge, the Canadian Agri-food Policy Institute (CAPI) organized three conversations in 2017-2018 that attempted to determine how the Canadian agricultural industry could best achieve sustainable growth.[1] CAPI concluded that "…we will require more than 'simple' growth to achieve the ambitious growth targets set out by the federal government's Advisory Committee on Economic Growth (ACEG), otherwise known as the Barton Report.[2] 'Quality' or 'clean' growth is needed to ensure that the gains in the agri-food sector can be sustainable for the future."[3]

This paper will explore the ways in which the Canadian agriculture sector can achieve "clean" growth. Four main components frame this report:

- *The current state of play between agriculture, the environment and climate change;*
- *Policies, programs, and community-based initiatives in Canada that strive to mitigate the impact of agriculture on the environment;*
- *Potential technological developments and innovative pathways to a zero-carbon economy; and*
- *Options to promote investments in this clean growth.*

The Global Context

Vibrant agriculture is key to feeding the world. Yet the impacts from food production are increasingly felt around the globe. "Feed the world or save the planet" is a stark choice, but if done well, modern agriculture and food systems hold the promise for doing both. If done sub-optimally, agriculture and food production pose significant risks to human health, animal, plant and microbial life and biodiversity, as well as air, water, and soil quality. Moreover, depending

1 CAPI "What we heard, Barton Forward, Optimizing Growth in the Canadian Agri-food Sector," June 22, 2018, pg. 2. Accessed at: https://capi-icpa.ca/wp-content/uploads/2018/06/CAPI_Barton_WhatWeHeardReport_Eng.pdf

2 Dominic Barton was appointed by the government in 2016 as head of the Advisory Council on Economic Growth (ACEG) to "develop advice on concrete policy actions to help create the conditions for strong and sustained long-term economic growth." Accessed at: https://www.budget.gc.ca/aceg-ccce/home-accueil-en.html.

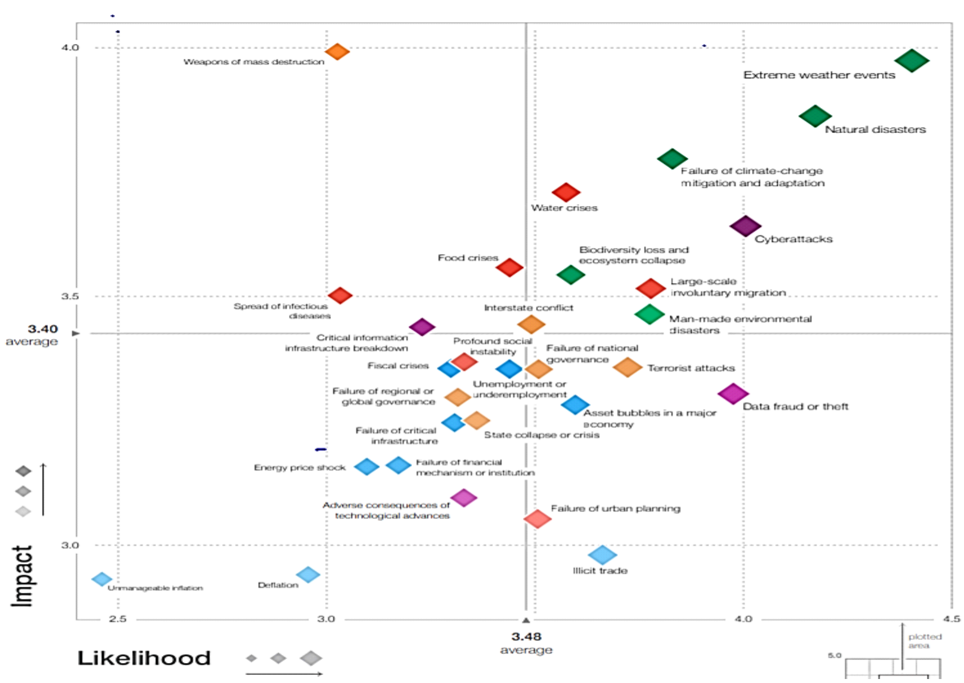
3 CAPI, "What we heard," pg. 2.

on the risk, local (think ground water contamination), regional (think biodiversity in ecozones) or international (think climate change) implications prevail.

From a production perspective, by 2050 it is predicted that the world's population will rise to just under 10 billion and to meet the nutritional needs of these global citizens, we will have to grow as much food between now and then as the planet has produced up until the present.[4] According to the UN, global agricultural production will need to increase by 70% by 2050 in order to feed the projected global population. This will require increased yields from productivity growth as well as more environmentally sustainable production.[5]

In its recent report on Global Risks (2019), the World Economic Forum (WEF) identified ten potential global crises that are most likely to occur and with the highest potential impact (Figure 1). Seven of the ten risks include extreme weather events, natural disasters, failure of climate-change mitigation and adaptation, water crisis, biodiversity loss and ecosystem collapse and food crises.[6]

Figure 1: Global Risks Landscape, 2019[7]



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4 Food and Agriculture Organization (FAO), "How to Feed the World in 2050," 2009. Accessed at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf and UN, "World Population Prospects: the 2015 Revision," 2015. Accessed at: http://www.un.org/en/development/desa/publications/world-population-prospects-2015-revision.html.

5 FAO, "The Future of Food and Agriculture: Challenges and Trends," 2017. Accessed at: file:///D:/FAO/a-i6583e%20the%20future%20of%20food%20and%20agricluture%20from%20the%20FAO.pdf.

6 World Economic Forum, "The Global Risks Report, 2019," 14th Edition, pg. 5. Accessed at: http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf.

7 WEF, Global Risks Report 2019, pg. 5.

To respond to these global risks and other challenges the world faces, the United Nations (UN) established 17 Sustainable Development Goals (SDGs) for both developing and developed countries. The objectives of the SDGs are to reduce poverty and hunger, improve the health of populations and end environmental degradation, climate change and waste by 2030.[8] According to the UN's estimates, on a global level, agricultural activities account for 60 per cent of terrestrial biodiversity loss, 24 per cent of greenhouse gas emissions, 33 per cent of soil degradation and 61 per cent of the depletion of commercial fish stocks since the 1970's.[9]

The depletion of soils is threatening future food security. The United States is losing soils 10 times faster, and China and India, 30 to 40 times faster than the natural replenishment rate.[10] However, agriculture has the capacity to be a solution-provider to prevent continual environmental degradation. Farmers have a role to play through education and awareness, and the adoption of better management practices, innovations and new technologies.

Despite recent short-term trade disputes and fluctuations, future growth opportunities for the sector are no doubt plentiful as the global demand for agricultural products continues to rise, and the fast-growing middle classes of emerging economies, such as China, demand more high quality, healthy food, at a time when the earth's capacity to produce is becoming more limited.

Decoupling economic growth and consumption from natural resource use could spearhead a clean growth strategy for the agriculture sector. This would provide an opportunity for agriculture to make a major contribution to enhancing natural capital and the mitigation of climate change. The question remains, how do we make this happen?

The Canadian Context

In Response to Barton: The Need for Quality Growth in Agriculture

In response to the fall in oil prices, a weakening economy, and the subsequent threat to Canada's growth rate and standard of living, Finance Minister Bill Morneau set up the Advisory Council on Economic Growth (ACEG), headed by Dominic Barton, to provide advice, which was given through the report *Unleashing the Growth Potential of Key Sectors*."[11] The Barton Report recommended that the government, in concert with the private sector, take a focused approach to removing growth obstacles – thereby unleashing the significant potential of key sectors, one of which was identified as the agriculture and agri-food sector. Moreover, the report recommended

[8] The United Nations 17 Sustainable Development Goals. Accessed at: https://www.un.org/sustainabledevelopment/, August 24, 2018.

[9] FAO, "The State of Food and Agriculture: Climate Change, Agriculture and Food Security," 2016. Accessed at: http://www.fao.org/3/a-i6030e.pdf.

[10] Global Footprint Network, The Living Planet Report, "Risks and Resilience in a New Era," 2016. Accessed at: https://www.footprintnetwork.org/content/documents/2016_Living_Planet_Report_Lo.pdf.

[11] Advisory Council on Economic Growth (ACEG), "Unleashing the Growth Potential of Key Sectors," February 6, 2017. Accessed at: https://www.budget.gc.ca/aceg-ccce/pdf/key-sectors-secteurs-cles-eng.pdf.

"launch[ing] an agri-food pilot by convening private and public sector stakeholders, identifying major obstacles to growth, setting an aspiration (a vision and quantified goals), and recommending concrete actions."[12]

The agriculture and agri-food sector was highlighted as a key growth sector for the first time since the late 19th century. It was chosen as the pilot to test the growth strategy primarily because of the anticipated growth in global demand for food and fiber and the availability of resources in Canada to increase production and exports of food. In the report, Barton established some ambitious growth targets for the Canadian agri-food sector, including an $11 B increase in agriculture exports, and a $19 B increase in processed food exports between now and 2025.[13]

There is a general consensus that the Barton growth targets for the sector can be achieved. However, because of the strong linkages between agricultural production and the environment, and the implications for Canada's future natural capital and climate change, Barton's growth targets can only be achieved with sustainability in mind.

The Netherlands in the Barton Report: Growth without Sustainability and Externalities

Despite its relatively small resource base, the Netherlands is the world's 3rd largest agri-food exporter. Barton used the Netherlands' Agri-food sector as an example of a country to emulate. Its success was outlined due to the country's emphasis on raising agricultural productivity, which allowed the Netherlands to surpass Canada and Australia in achieving "the highest growth rate in both exports and total factor productivity over the past 50 years."[14] This comparison is problematic for two reasons:

- The Netherlands has several advantages not available to Canada. About 75% of the Netherland's agri-food exports are destined for the EU market, which is unfettered by border measures or standards that otherwise disadvantage non-EU exporters, like Canada.
- Evidence shows that the productivity gains and high level of exports from the Netherlands have been achieved at considerable environmental costs and with no consideration for the future sustainability of the sector. The production practices used contribute significantly to environmental degradation (or negative externalities).[15]

Using the example of The Netherlands, it is estimated that while Dutch agriculture generated an average of €10.3 billion in sales annually, **negative externalities** of €1.9 billion (mostly air and water pollution) and **positive externalities** of €0.3 billion were estimated.[16]

[12] Ibid, pg. 3.
[13] Ibid, pg. 11-12.
[14] Ibid, pg. 5.
[15] R. Jongeleel, N. Polman and G. Cornelius van Kooten, "How Important are Agricultural Externalities? A Framework for Analysis and Application to Dutch Agriculture," University of Victoria, Working Paper 2016-04, Resource Economics and Policy Analysis Research Group, June 2016, pg. 22.
[16] Ibid, pg. 11.

What is meant by externalities?

Externalities are normally associated with unintended or uncompensated impacts of agriculture on the environment, both positive and negative. Examples of positive externalities include carbon sequestration or increased habitat for wildlife. Examples of negative externalities include air or water pollution from fertilizer run-off or GHG emissions from agricultural production.

Externalities are considered market failures, since the market fails to include the negative external costs in the production costs for the farmer creating the externality. Also, farmers generally do not take these environmental impacts into account when producing their crops or raising livestock. There is a role for the government in correcting these negative externalities.

In the absence of policies and systems to internalize the external costs associated with agriculture, any factor that encourages production, such as higher prices or production subsidies, exasperates the magnitude of negative externalities. It is well-known that certain government programs that provide domestic support to agriculture in major producing areas, such as the EU and the US, encourage production beyond levels dictated by market forces and exasperate negative externalities.

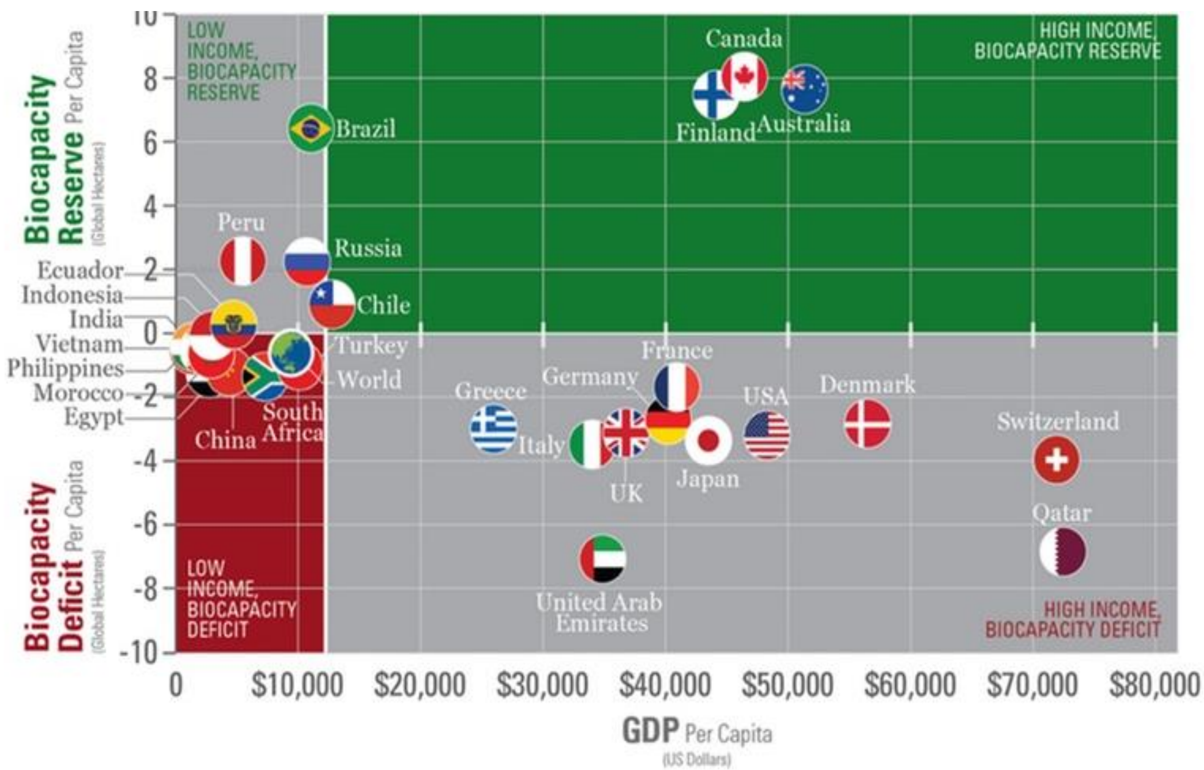
Agriculture and its Environmental Impacts in Canada

Canada is the world's second largest country in terms of land mass, and contains plentiful freshwater, forests and wildlife resources. Approximately 6.9% of land in Canada is considered dependable agricultural land, and only 4.8% is suitable for crop production.[17] Agricultural lands are generally clustered along Canada's southern-most geopolitical boundary, where there is adequate water and sunlight, suitable heat units, and sufficient mineral soils to support agricultural activity.[18] The Prairie region accounts for 60% of dependable agricultural land, while the Central Region (Ontario and Quebec) has ample agricultural land, but accounts for only about 20%, with the rest in pockets in British Columbia and Atlantic Canada.

This abundance of natural resources gives Canada a major comparative advantage as a global agricultural producer. Overall, Canada is privileged to be one of a very few countries with high income *and* high biocapacity reserve, along with Finland and Australia (Figure 2).[19] Countries with a high "biocapacity reserve" generally have the natural resource base and ecological assets to exceed their citizens' "ecological footprint" (i.e. consumption). As a result, they are able to export their resources without liquidating their national ecological assets or emitting carbon dioxide waste into the atmosphere.

[17] Statistics Canada, "Human Activity and the Environment: Agriculture in Canada, 2014," pg. 19. Accessed at: https://www150.statcan.gc.ca/n1/en/pub/16-201-x/16-201-x2014000-eng.htm.
[18] Ibid.
[19] Global Footprint Network. Accessed at: https://data.footprintnetwork.org/#/?/.

Figure 2: Biological Reserves/Deficits by Country[20]

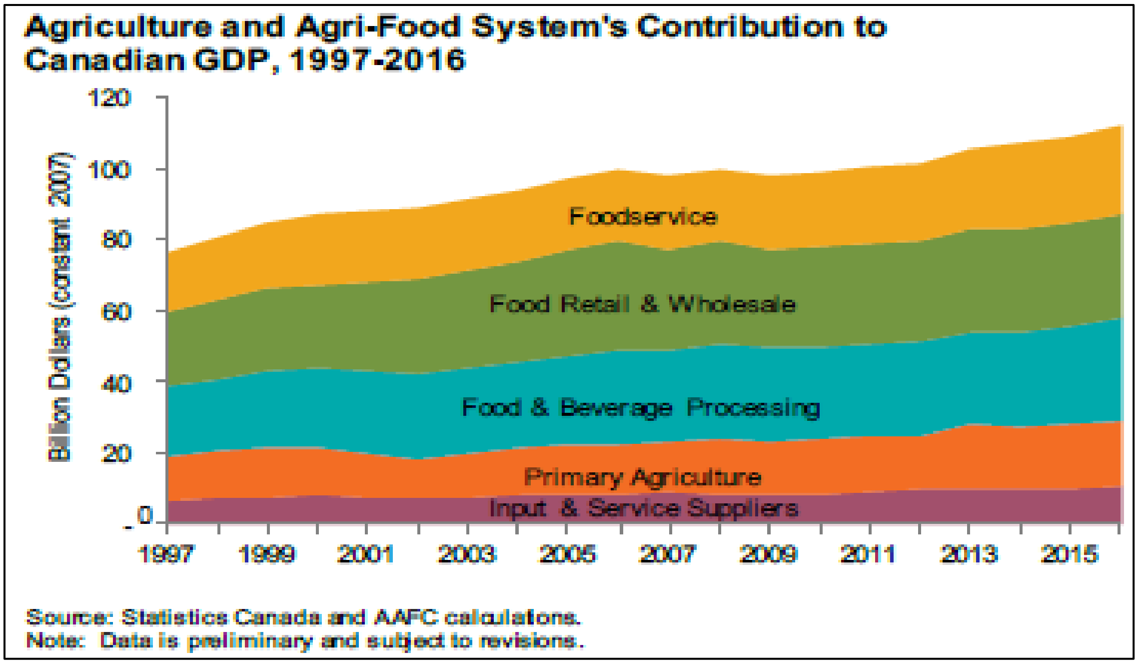


With a stable share of just under 7% GDP over the last ten years, the Agriculture and Agri-Food System (AAFS) is a significant contributor to Canadian GDP (Figure 3).[21] It employs approximately 2 million Canadians. The Food and Beverage Processing sector's share of total manufacturing GDP, at 16.4%, makes it the largest manufacturing industry in Canada. While the Primary Agriculture sector may only represent about 2% of Canadian GDP, it has an important role to play in clean growth and sustainability.

[20] Ibid.

[21] The AAFS includes farm input suppliers, primary agriculture, food and beverage processing, food wholesale and retailing and food service, which is a broader definition than that used by Barton in his agri-food analysis (primary agriculture and food, beverage and seafood processing only). Source: Agriculture and Agri-food Canada, "An Overview of the Agriculture and Agri-food System," 2017. Accessed at: http://www.agr.gc.ca/eng/about-us/publications/economic-publications/an-overview-of-the-canadian-agriculture-and-agri-food-system-2017/?id=1510326669269.

Figure 3: Agriculture and Agri-Food's Contribution to Canadian GDP[22]



The agriculture sector provides more than just food for human and animal consumption. The agriculture sector also supplies biomass to produce bio-products, such as ethanol and biodiesel. These products are considered greener substitutes for fossil fuels and have been targeted for climate change mitigation. Only about 3% of agricultural production is used as biomass for the production of bioproducts in Canada.[23]

However, international organizations currently recommending avoiding any further expansion in first generation biofuel production (i.e. ethanol from corn and biodiesel from canola), so it can be used to feed the growing world population.[24] According to the UN, global agricultural production will need to increase by 70% by 2050 in order to feed the projected global population of 9 billion. This will require increased yields from productivity growth as well as more environmentally sustainable production.

[22] Statistics Canada and AAFC Calculations.

[23] The two major crops used as biomass in the bioprocessing sector are corn and canola. Corn is used to make ethanol and canola is used to make biodiesel. Canada tends to be a net importer of corn, which means any increase in the demand for corn must be met by imports from the US. While canola is one of Canada's major export products. In 2015, 1.8 million tonnes of Canadian canola seed were used to produce biodiesel in Canada. Canola exported for biodiesel production was about 16% of total exports and about 8% of total production.

[24] Searchinger, Tim and Ralph Heimlich, "Avoiding Bioenergy Competition for Food Crops and Land," Working Paper, Installment 9 of Creating a Sustainable Food Future, World Resources Institute. Accessed at: https://www.wri.org/sites/default/files/avoiding_bioenergy_competition_food_crops_land.pdf.

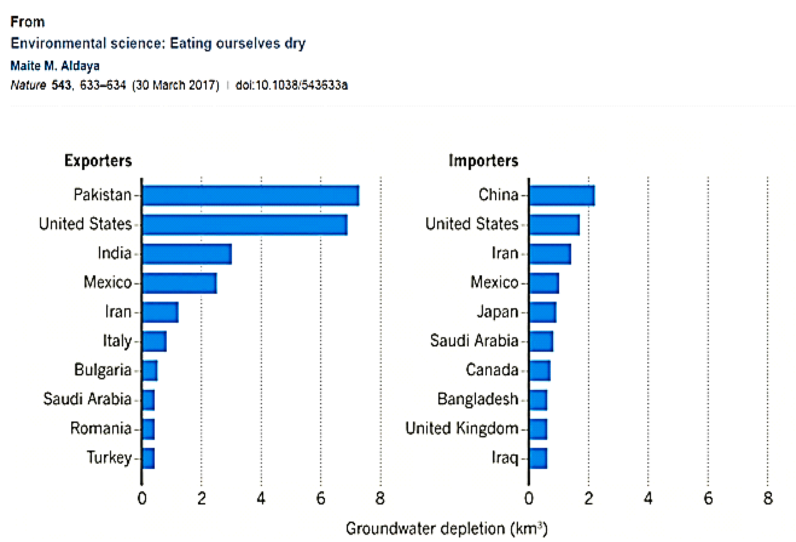
A Closer Look at the Environmental Performance of Canadian Agriculture

In its most recent Environmental Performance Report (2017), the Organization for Economic Cooperation and Development (OECD) reported that Canada faces pressures from urbanization and agriculture on its natural asset base.[25] This includes pressures affecting water availability and quality, biodiversity, air, climate change, and land use. Agri-environmental indicators produced by Agriculture and Agri-food Canada (2016) provide a snapshot of the sector's environmental performance below.[26]

Water

Water use in agriculture is a growing global concern. There is increasing recognition that many countries' agriculture depends on non-renewable groundwater depletion. About 70% of the world's fresh water withdrawals are used for irrigating crops.[27] In addition, over 11% of groundwater used for irrigation in agriculture is embedded in the international food trade. Two thirds of the world's groundwater are embedded in food exports from Pakistan, the USA, and India alone (Figure 4). Some countries such as the US, Mexico, Iran and China are particularly at risk of groundwater depletion because they produce, and export food produced on irrigated land using water from rapidly depleted aquifers.[28]

Figure 4: Top ten exporters and importers of ground water depletion embedded in food trade[29]



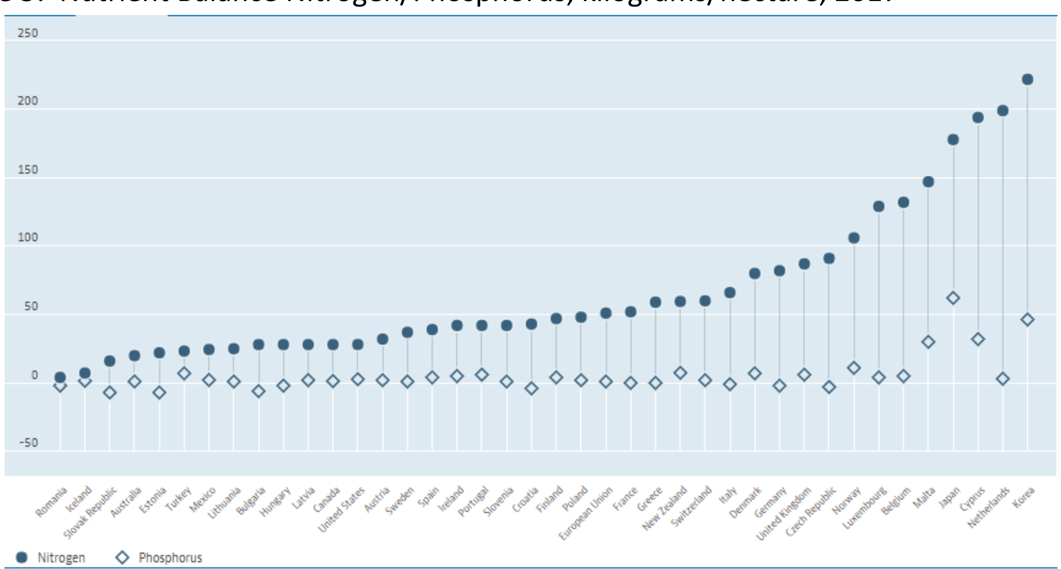
[25] OECD, "OECD Environmental Performance Reviews: Canada 2017.: Accessed at: https://doi.org/10.1787/9789264279612-en.
[26] AAFC, Agri-Environmental Indicators Report #4, "Environmental Sustainability of Canadian Agriculture," 2016.
[27] Food and Agriculture Organization of the United Nations (FAO), "The Future of Food and Agriculture: Challenges and Trends," 2017, pg. 36. Accessed at: http://www.fao.org/3/a-i6583e.pdf.
[28] Maite M Aldaya, "Eating Ourselves Dry," in Nature, March 30, 2017, pg. 543, 633-634. Accessed at: https://www.nature.com/articles/543633a.
[29] Ibid.

Canada has 7% of the world's renewable water supply, which makes it the third largest renewable freshwater supplier in the world.[30] On a per capita basis, it has the second largest amount of water among developed countries. Nevertheless, water is one of Canada's natural resources that face pressure from urbanization and agriculture. Some regions in Canada face water scarcity, particularly along the southern border and in densely populated areas. Nearly 20% of monitored water sites register marginal or poor water quality, due to nutrient pollution from agricultural run-off (i.e. fertilizer and manure) and urban wastewater sources, persistent toxic substances and chemicals (i.e. pesticides and herbicides). Lake Erie and Lake Winnipeg, for example, which are both quite shallow, suffer increasingly from eutrophication and water pollution issues.[31]

Fertilizer use has increased more than twice as fast as agricultural production since 2000. Areas of highly concentrated agricultural production have led to increased nutrient run-off into waters such as the Great Lakes, Lake Winnipeg and the St. Lawrence River basin. Phosphorous run-off from livestock (dairy) production has also contributed to a decline in water quality in Canada since 1981, particularly in Ontario and Quebec.[32]

According to the OECD, Canadian agriculture uses significantly less fertilizers (i.e. nitrogen, phosphorous) per unit of land basis, compared to other countries, resulting in a lower environmental impact (Figure 5).[33]

Figure 5: Nutrient Balance Nitrogen/Phosphorus, kilograms/hectare, 2017[34]

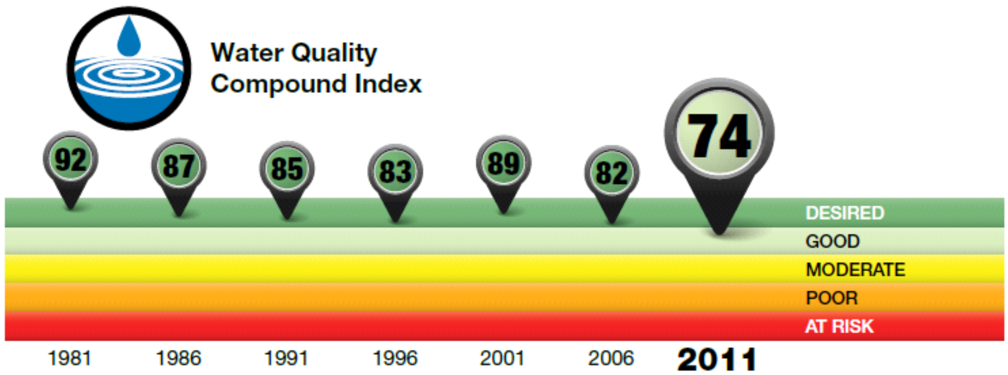


Despite the fact

[30] Statistics Canada, "Human Activity and the Environment: Freshwater in Canada," Catalog 16-201-X, 2017.
[31] Agriculture and Agri-Food Canada (AAFC), "Environmental Sustainability of Canadian Agriculture," Report #4, Agri-Environmental Indicators Report Series, 2016, pg. 132.
[32] Ibid.
[33] OECD, "OECD Compendium of Agri-Environmental Indicators," 2013, pg. 123. Accessed at: https://read.oecd-ilibrary.org/agriculture-and-food/oecd-compendium-of-agri-environmental-indicators_9789264186217-en#page123. "Environmental Performance Review: Canada," 2017, pg. 75. Accessed at: https://read.oecd-ilibrary.org/environment/oecd-environmental-performance-reviews-canada-2017_9789264279612-en#page1.
[34] OECD. Accessed at: https://data.oecd.org/agrland/nutrient-balance.htm.

that Canada uses significantly less nitrogen compared to most other countries, indicators of water quality have worsened over time as measured by the risk of nitrogen contamination (Figure 6). The risk of nitrogen-related water contamination is high for 7% of farmland in Canada. However, by province, the risk of nitrogen-related water contamination is particularly high in Ontario at 41% of farmland, and Quebec, at 75%.[35]

Figure 6: Water Quality Compound Index, 2011[36]



In terms of pesticide use, Canada ranked below many of its counterparts as measured by pesticide use per unit of agricultural land, using far less than Japan, the Netherlands and other European countries. Nevertheless, the risk of pesticides contaminating groundwater has increased, which is contributing to Canada's deteriorating water quality since 1981. This is primarily due to urbanization and agricultural production, which has had consequences for both biodiversity (fish and wildlife) and human recreational activities in Canada.[37]

Biodiversity

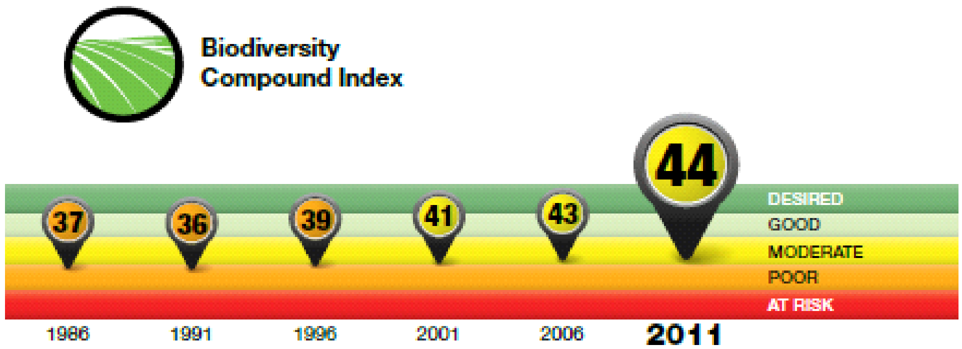
As global agricultural production expands, areas of mature forests are projected to shrink by 13%. Land use changes, including deforestation, conversion to large monoculture crop areas and increased pesticide use, are major culprits in the loss of biodiversity globally. Polluted streams and waterbodies also contribute. According to the OECD about one-third of biodiversity in rivers and lakes worldwide has already been lost.[38] The insect population, which is another indicator of biodiversity health, is globally in decline. The World Wildlife Fund (WWF) estimates that populations of invertebrates declined by about one third between 1970 and 2008.[39]

Biodiversity in Canada, as measured by AAFC's agri-environmental indicators, has improved only marginally over the past decade (Figure 7). This indicator is a combination of soil cover and

[35] AAFC, "Environmental Sustainability of Canadian Agriculture," Report #4, 2016, pg. 117.
[36] Ibid.
[37] OECD, "Environmental Performance Reviews Canada, 2017: Highlights," pg. 14. Accessed at: file:///D:/BIODIVERSITY/Highlights_OECD_Environmental_Performance_Review_Canada2017%20(1).pdf.
[38] OECD, "Environmental Outlook to 2050," 2015. Accessed at: http://www.oecd.org/env/indicators-modelling-outlooks/oecdenvironmentaloutlookto2050theconsequencesofinaction-keyfactsandfigures.htm.
[39] World Wildlife Fund, Living Planet Report, 2012. Accessed at: http://d2ouvy59p0dg6k.cloudfront.net/downloads/lpr_living_planet_report_2012.pdf.

wildlife habitat indexes. The marginal improvement was primarily the result of improved soil cover, due to more conservation till and less summerfallow, and improved farm management practices. On the other hand, the wildlife component of this indicator, showed a significant decline since 1996. By 2011, the state of wildlife habitat capacity on farmland in Canada was poor, with 14% of farmland reporting major declines. This was due to the loss of natural and semi-natural land and the intensification of farming. In Eastern Canada, in particular, the loss of perennial hay and pasture habitat was a major contributor to this decline.[40]

Figure 7: Biodiversity Compound Index, 2011[41]



In its recent report on Canada, the WWF (2017) reported that half of our monitored species are in decline, with an average decline of 83% in numbers over the 1970 to 2014 period.[42] Some wildlife groups have experienced larger declines than others: 54% of mammals, 51% of fish, 48% of birds and 50% of amphibians and reptiles have experienced declining populations since 1970. For species at risk (SAR) in Canada, in particular, populations declined by 43% between 1970 and 2002, and after legislation was introduced in 2002, populations declined by 28% (between 2002 and 2014). While some measures introduced, such as tight restrictions on dangerous chemicals (ie. DDT), limits on fishing and hunting, and restoring wetlands (ie. DUC, ALUS and the Nature Conservancy of Canada (NCC))[43], there are still measures that are needed to prevent further declines. Agricultural producers can play a role through adopting BMPs, while government and voluntary sector initiatives (eg. ALUS, DUC, NCC) can also help protect wildlife habitat.

Figure 8 shows how grassland bird and aerial insectivore populations have been declining over this period. The progress made in Canada for increasing populations of waterfowl and non-migrating raptors, has been the result of conservation initiatives targeting wetlands and chemical

[40] AAFC, Agri-Environmental Indicators Report #4, 2016. "Biodiversity Compound Index", pg. 2. Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/environmental-sustainability-of-canadian-agriculture-agri-environmental-indicator-report-series-report-4/?id=1467307820931

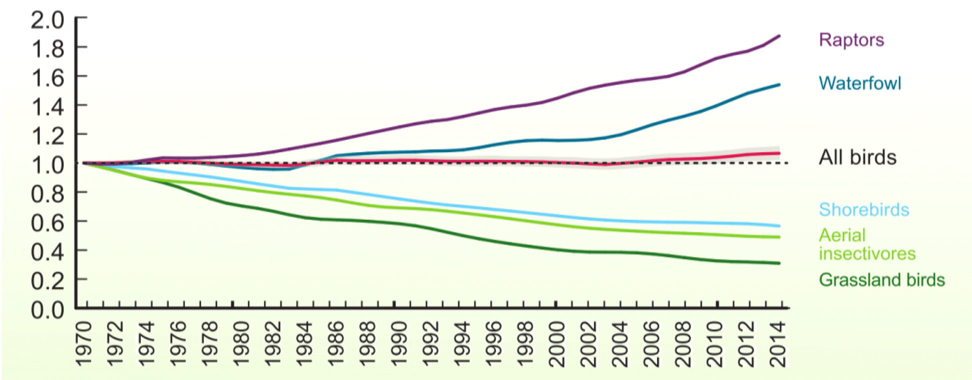
[41] Ibid.

[42] WWF, Living Planet Report Canada: A National Look at Wildlife Loss, 2017. Accessed at: http://assets.wwf.ca/downloads/WEB_WWF_REPORT_v3.pdf?_ga=2.205559251.1395350973.1551302744-1261428338.1551302744.

[43] These initiatives are described in more detail in Annex B.

pesticide bans, in both Canada, as described above and internationally (ie. the North American Waterfowl Management Plans partnership)[44].

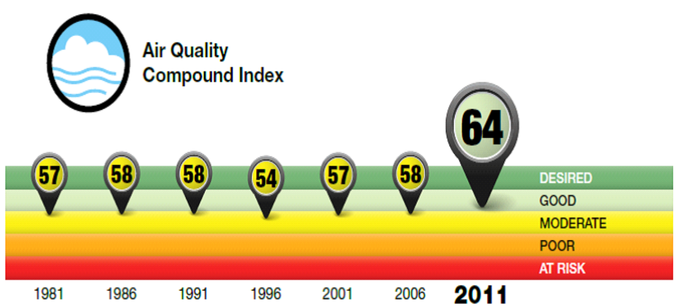
Figure 8: Changes in Canada's Bird Populations[45]



Air Quality

Compared with many OECD countries, Canada generally has good air quality. Recently, outdoor air quality regulations have been strengthened and emissions standards established. According to AAFC indicators, agriculture's negative impact on air quality has been reduced significantly since 1996, primarily due to reduced particulate matter (PM) in the air and stable GHG emissions (Figure 9).[46] However, about 30% of Canadians live in areas where outdoor levels of fine particulate matter (PM2.5) and/or ozone exceed national air quality standards. This is found mostly in cities in Ontario and Quebec.

Figure 9: Air Quality Compound Index, 2011[47]



[44] The North American Waterfowl Management Plan (NAWMP) is an international partnership that conserves and protects wetland and upland habitats, and associated waterfowl populations by connecting people with nature. This website provides information on the Plan and the Canadian approach to its implementation.

[45] Ibid.

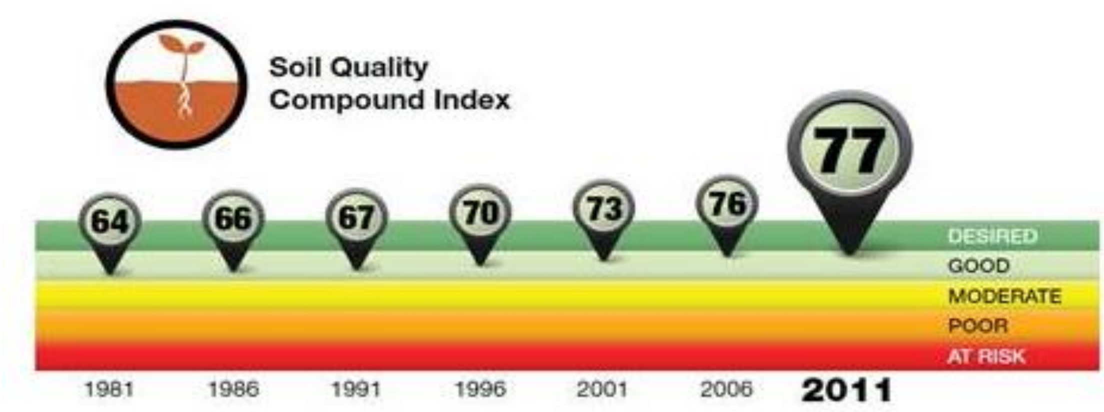
[46] AAFC, "Environmental Sustainability of Canadian Agriculture," Report #4, 2016, pg. 5.

[47] AAFC, "Agri-Environmental Indicators Report # 4, 2016. "Biodiversity Compound Index," pg. 2. Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/environmental-sustainability-of-canadian-agriculture-agri-environmental-indicator-report-series-report-4/?id=1467307820931.

Soil Health

Soils are the foundation of agricultural production and require adequate soil organic carbon (SOC) and a healthy microbiome to remain productive. Soils play a very important role in both contributing to and mitigating Climate Change. In Canada, during the late 1800s and early 1900s, the conversion of native grasslands to croplands on the Prairies, and the loss of the native grazing bison herd, caused a depletion of as much as 60% of the SOC in the first meter of the soil profile.[48] These losses of carbon and other nutrients were exacerbated by poor management practices, severe wind erosion and a period of extremely dry climate, which led to the abandonment of over 3M ha of cultivated prairie land between 1930 and 1938. As native vegetation returned to these lands, soil carbon levels rose with full restoration occurring over the last 70 years. Best management practices, such as conservation tillage, crop rotation, rotational grazing, cover crops, and the sowing of perennial grasses on native grassland have all contributed to the restoration of lost soil carbon.[49] This has resulted in significant improvement in soil quality over the period 1981-2011 (Figure 10).

Figure 10: Soil Quality Compound Index, 2011[50]



While the overall soil quality in Canada has improved, national averages mask significant regional differences. For example, 56% of cropland in Ontario and 80% of cropland in Quebec are experiencing large decreases in SOC. On the other hand, 79% of cropland in Saskatchewan experienced a large increase in SOC. This is largely due to differences in agro-climatic conditions, as the Prairie region has soil and climate that is more amenable to reduced-till and no-till practices, while in Central Canada, soil type and moisture conditions are less amenable to these practices.

[48] S. Bohm-Woods, "Agricultural Soils as a Solution Provider to Climate Change," for CAPI, October 2018, pg. 6. Accessed at: https://capi-icpa.ca/wp-content/uploads/2018/10/2018-1012-CAPI-paper-AG-SOILS-SOLUTION-PROVIDER-CLIMATE-CHANGE.pdf.

[49] AAFC, "Environmental Sustainability of Canadian Agriculture," Report #4, 2016, pg. 82.

[50] AAFC, Agri-Environmental Indicators Report # 4,2016. Pg. 3. Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/environmental-sustainability-of-canadian-agriculture-agri-environmental-indicator-report-series-report-4/?id=1467307820931.

A recent analysis by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) estimated that 82% of Ontario's agricultural soils are net carbon emitters, 68% of Ontario's farmland is in an unsustainable erosion risk category, and 53% of Ontario's cropland have low or very low soil cover.[51] However, the improvement on the Prairies far exceeds these declines, resulting in improved soil quality in Canada overall. Between 1981 and 2011, soil organic carbon in Prairie soils rose from 9 kg/ha/yr to 97 kg/ha/yr. Regarding risk of soil erosion, Alberta, Saskatchewan and Manitoba reported 87%, 78% and 67% of cropland with very low risk of soil erosion, compared to 32% of cropland in Ontario and 77% in Quebec. [52]

Mitigating Climate Change through Carbon Capture and Storage

While agricultural production can yield substantial GHG emissions, it can also capture carbon from the atmosphere – a process known as **biological carbon sequestration**. Regardless of the commodities produced, agriculture is based on the production and use of plants, which uniquely rely on photosynthesis to capture atmospheric carbon to support their growth. Plants can remove carbon from the atmosphere and contribute a portion of that carbon to stable pools in the soil. Once crops mature and are harvested, much of the carbon captured in them is removed from the field, but the rest that is in the root system and in the residual plant material serves as carbon feedstock for ingestion by the microbial community that transforms it to soil organic carbon (SOC).[53]

The destiny of SOC depends on what happens to the soils next. Soils under permanent cover, such as grasslands, soils on which cattle graze and soils that are used for crop production have different carbon (C) sequestration potential. With careful management, the amount of carbon sequestered in the soil for longer-term storage can exceed the amount of carbon emitted by the associated agricultural activities, so that soils can act as a net sink for carbons that might otherwise be emitted into the atmosphere. In the context of this analysis, carbon sequestration is one of the benefits (or positive externalities) of agricultural production, helping mitigate Climate Change

Carbon sequestration is an important means by which Canadian agriculture producers could contribute to Climate Change mitigation. Since about 2000, agricultural lands have become a net sink for CO2 when land use changes are considered.[54] This is particularly important for livestock producers who manage pastures and grazing lands where carbon can be stored.

[51] OMAFRA, "New Horizons-Ontario's Soil Health and Conservation Strategy," April 2018, pg. 12. Accessed at: http://www.omafra.gov.on.ca/english/landuse/soilhealth.htm.

[52] AAFC, Agri-Environmental Indicators Report # 4,2016. "Soil Erosion Indicator". pg. 85 Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/environmental-sustainability-of-canadian-agriculture-agri-environmental-indicator-report-series-report-4/?id=1467307820931

[53] Bohm, Susan-Wood, "Agricultural Soils as a Solution Provider for Climate Change," pg. 5.

[54] AAFC, Science and Technology Branch, "Measuring Greenhouse Gases." Accessed at: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/climate-change-and-agriculture/greenhouse-gases/measuring-emissions/?id=1329321977257.

Research shows that by increasing soil carbon sequestration in Canadian soils by 0.4% per year, the agriculture sector could offset its entire annual agriculture sector emissions.[55]

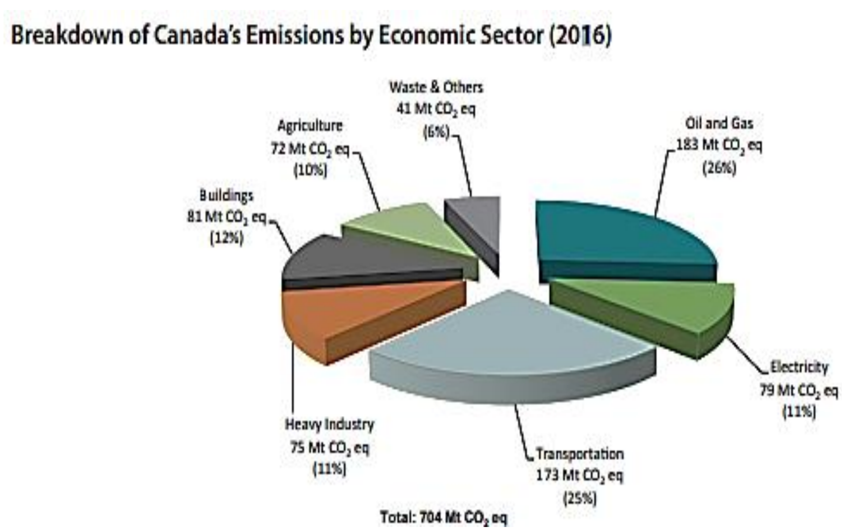
Greenhouse Gas Emissions

Relative to global GHG emissions, Canada is the fourth largest emitter of GHGs and the second most energy and carbon intensive economy in the OECD. However, these comparisons are all presented on a per capita basis, which is not a particularly fair comparison, given that Canada exports a large share of its production, to be consumed in other countries. Over time, Canada's total GHG emissions have decreased slowly between 2000-2015, by about 2% per year, compared to the average annual decrease in the OECD overall (about 5%).[56] In fact, a more appropriate indicator would be GHG intensity, as measured by GHG emissions on a per unit of land or output basis.

GHG emissions from agriculture accounted for approximately 10% of Canada's total GHG emissions in 2016.[57] Approximately 15% of this amount is from on-farm use of fossil fuels for farm machinery, heating barns and grain drying. The remainder is the outcome of biological processes related to crop and livestock production.

In 2016, the oil and gas industry accounted for one quarter (26%) of total emissions; but adding in fuel combustion by power plants for electricity generation, industry and transportation brings the energy sector's contribution to more than 80% of total Canadian GHG emissions (Figure 11).

Figure 11: Breakdown of Canada's Emissions by Economic Sector, 2016[58]



Note: Direct emissions from agricultural processes, excluding combustion of fossil fuels account for 8.5% of total emissions, or 60 Mt CO2-e in 2016.

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[55] Janzen and McConkey, "Measuring Change in Soil Organic Carbon Storage," March 2016.

[56] OECD, "Environmental Performance Reviews Canada, 2017: Highlights," pg. 12.

[57] ECCC, "National Inventory Report on Greenhouse Gas Sources and Sinks in Canada, 1990-2016." Accessed at: http://publications.gc.ca/collections/collection_2018/eccc/En81-4-2016-3-eng.pdf.

[58] ECCC, "National Inventory of Emissions," 2018.

GHG emissions in agriculture originate from four sources:

- **Direct emissions:** nitrous oxide **(N_2O)** from fertilizer applications and methane **(CH_4)** from animal production and rice cultivation;
- **Activities that release soil carbon reserves:** (tillage, mono-cropping, deforestation).
- **Carbon dioxide (CO_2) emissions:** from fossil fuel used by farm equipment, heating barns and drying grain; and
- **Indirect CO_2 emissions: arising from** fossil fuel use in the production of agricultural inputs such as pesticides or fertilizer.

Slightly more than 50% of agricultural emissions arise from livestock production and manure management, with the remainder coming from cultivation of agricultural soils, and nitrogen fertilizer use.[59] While the contribution of agriculture to Canadian GHG emissions is relatively small, its contribution to national CH_4 emissions is quite large, at 27% of the total. The sector also accounts for a relatively large share of N_2O emissions, at 70%.[60]

Greenhouse Gas Emissions from Agriculture

Nitrogen (N)

In agriculture, nitrogen is needed to be added to soils as a fertilizer to promote crop yields. It is a critical factor to both plant growth and for microbial processes for transforming plant residue to Soil Organic Carbon (SOC) which enriches soil quality for moisture retention and crop nutrition. Unfortunately, surplus nitrogen applied to soils as fertilizer has the potential to contribute to air pollution through evaporation as nitrous oxides (N_20) and to water pollution when it leaches into groundwater through run-off. Nitrous oxide has a CO_2 Equivalent of 298 (i.e. Releasing 1 kg of N_2O into the atmosphere is equivalent to releasing 298 kg of CO_2).

Methane (CH_4)

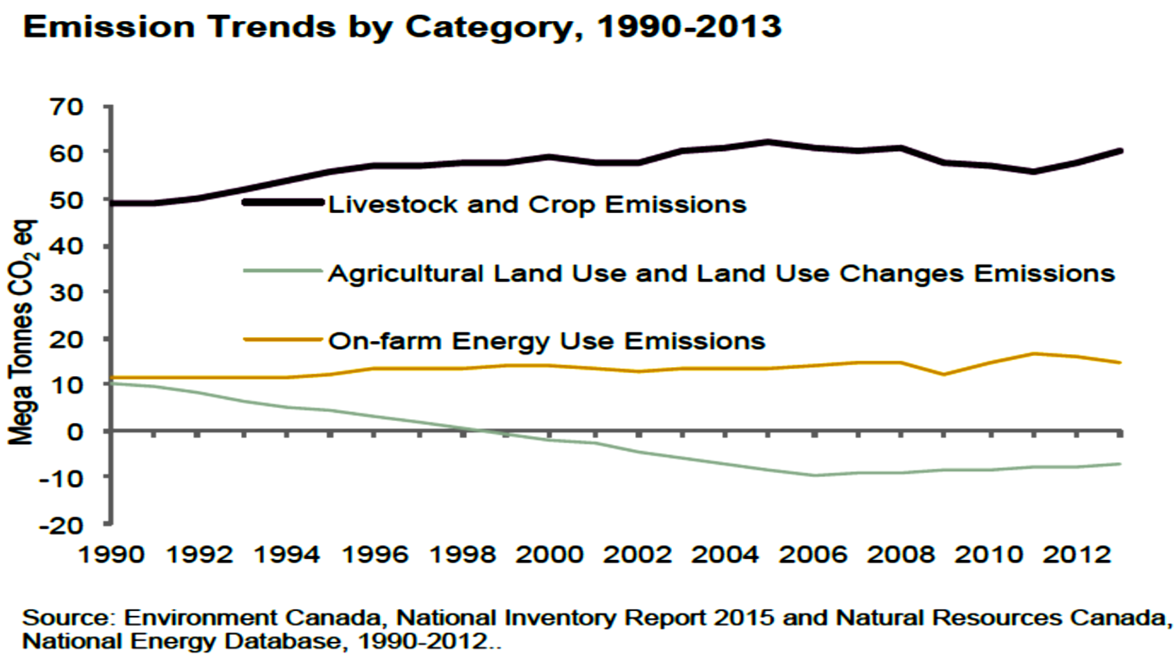
Methane is primarily derived from the livestock sector from animal manure as well as the bovine digestion process, known as enteric fermentation. Methane is also derived from rice cultivation, when plant material rots in water. Methane has a CO_2 equivalent of 25 (i.e. by releasing 1 kg of CH_4 into the atmosphere is equivalent to releasing 25 kg of CO_2). This is why livestock emissions account for half of agricultural emissions.

[59] Prairie Climate Centre, 2018. Accessed at : http://prairieclimatecentre.ca/.
[60] Mitigation Working Group Report, 2016. Accessed at: https://www.canada.ca/content/dam/eccc/migration/cc/content/6/4/7/64778dd5-e2d9-4930-be59-d6db7db5cbc0/wg_report_specific_mitigation_opportunities_en_v04.pdf.

The value of Canadian agricultural production more than doubled since 2007,[61] while GHG emissions from agricultural activity remained relatively stable (Figure 12). This led to a decline in GHG emissions per unit of output or intensity. In absolute terms, GHG emissions from land use change have declined significantly, while those from on-farm energy use have been stable, and from crop and livestock production, have increased slightly.

These changes are due to the introduction of various Best Management Practices (BMPs), new technologies and innovations and policies to encourage them. Examples include zero/reduced till cultivation, the use of cover crops, improved animal genetics and feeding efficiency and the more recent introduction of the 4R fertilizer stewardship program.[62]

Figure 12: Emission Trends by Category, 1990-2013[63]



Much like soil health, differences in the sources of GHG emissions vary greatly by province. This reflects the various agronomic conditions, product mixes, and the relative size of the agriculture sector in each province (Figure 13).

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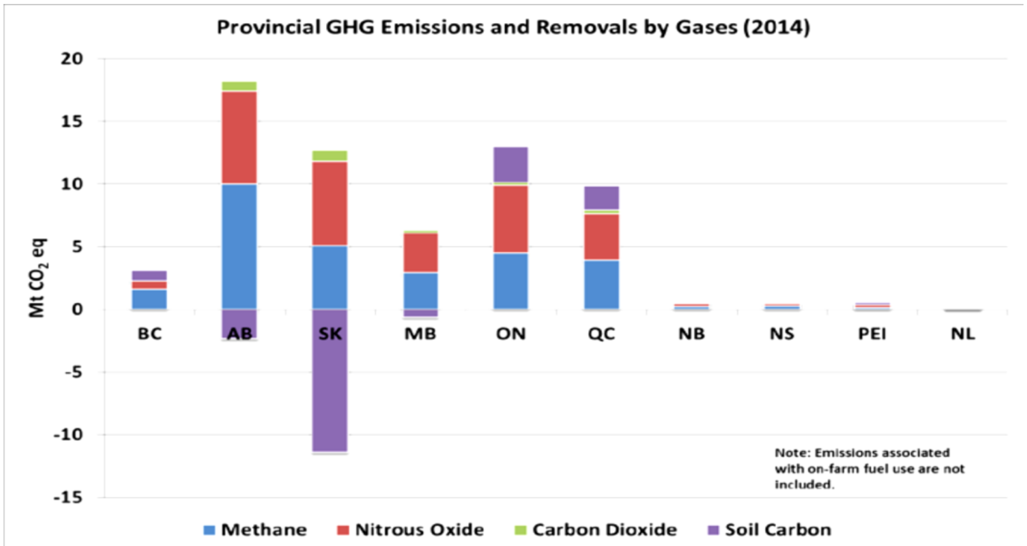
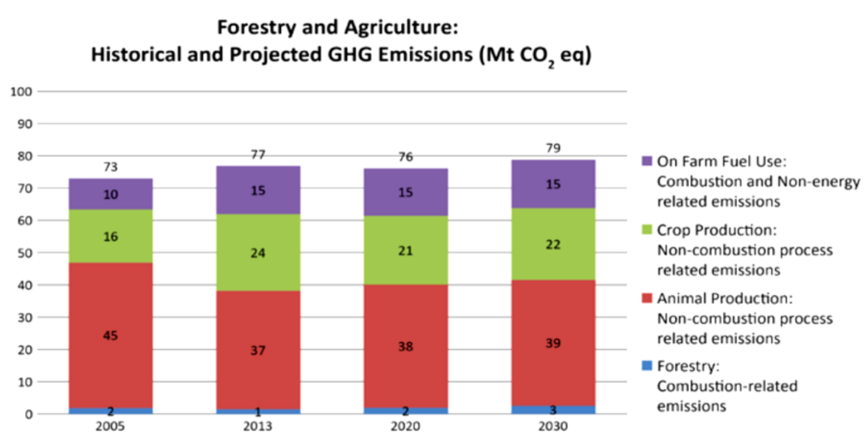
[61] As measured by GDP growth in constant 2007 dollars. AAFC, "Medium Term Outlook for Canadian Agriculture," 2017. Accessed at: http://www.agr.gc.ca/eng/about-us/publications/economic-publications/2018-medium-term-outlook-for-canadian-agriculture/?id=1536863615431.
[62] This program introduced and promoted by the Fertilizer Institute, and in Canada by Fertilizer Canada, provides information and training as well as certification on the optimal application of manure and fertilizers to ensure the right source, the right rate, the right time and the right place for sustainable and profitable agricultural production. Accessed at: http://www.nutrientstewardship.com/.
[63] Environment Canada, National Report 2015 and Natural Resources Canada, Energy Database, 1990-2012.

Figure 13: Provincial GHG Emissions and Removals by Gases, 2014[64]



Projections for GHG emissions out to 2030, as estimated by the Mitigation Working Group (MWG), show that emissions from crop and animal production to 2030 are expected to remain more or less at current levels (Figure 14).[65]

Figure 14: Forestry and Agriculture: Historical and Projected GHG Emissions[66]



However, MWG projections assume that there will be no disruptive technological changes or major policy changes in agriculture. Canadian agriculture, as a whole, has steadily reduced its GHG emissions intensity as a result of dramatic disruptive technological changes. The efforts by governments, industry and academia continue to enable the industry to reduce its emissions. The

[64] MWG Report, 2016.
[65] Mitigation Working Group Report, 2016. Accessed at: https://www.canada.ca/content/dam/eccc/migration/cc/content/6/4/7/64778dd5-e2d9-4930-be59-d6db7db5cbc0/wg_report_specific_mitigation_opportunities_en_v04.pdf.
[66] MWG Final Report, 2016.

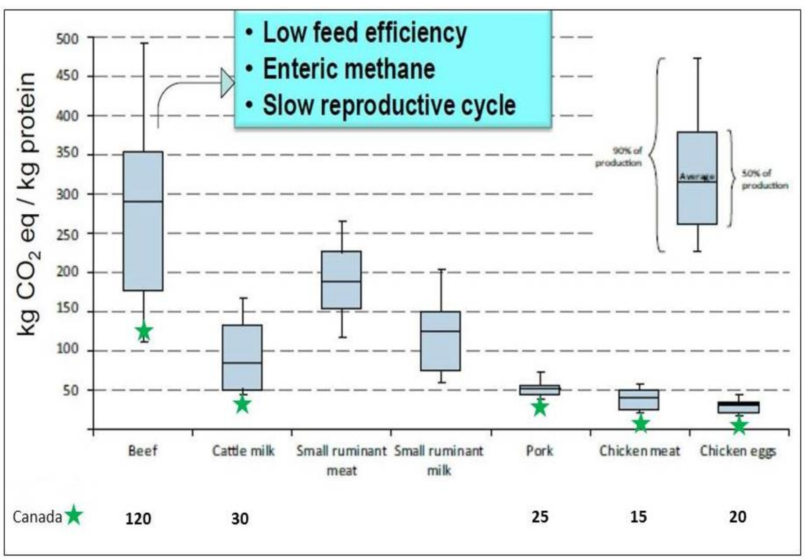
right combination of programs, incentives and policies could accelerate this transition towards becoming a net sink and providing solutions for the rest of the economy. Hence, the business-as-usual case may be overestimating GHG emissions and underestimating future opportunities.

Livestock

Given the contribution of livestock production to GHG emissions in agriculture, it is vital that the sector learns how to secure clean growth to the benefit of improved C-sequestration, water management and biodiversity.

Much effort is being made to reduce GHG emissions from livestock production. One such example is described in a recent study summarizing the dramatic gains that have been made in reducing GHG emissions intensity in the cattle sector between 1981 and 2011.[67] As a result of improved reproductive efficiency, reduced time to slaughter, increased crop yields, and a shift towards high-grain diets that enabled cattle to be marketed at an earlier age, GHG intensity fell by 14% between 1981 and 2011 in Canada (Figure 15). This makes Canada one of the most GHG efficient producers of animal protein in the world at 12 kg CO_2 equivalent per kg of live weight, less than half the world average.[68] This combined with the fact that Canada has one of the lowest livestock intensities in the OECD countries, suggests that Canada does have a comparative advantage and could produce environmentally sustainable beef for export to high quality markets. This could be a salient component of an agri-food growth strategy but requires these properties to be certified and branded to monetize the benefits to society.

Figure 15: GHG Emissions Intensity of Canadian Livestock[69]



[67] G. Legesse, K. A. Beauchemin, K. H. Ominski, E. J. McGeough, R. Kroebel, D. MacDonald, S. M. Little and T. A. McAllister, "Greenhouse gas emissions of Canadian beef production in 1981 as compared with 2011," Anim. Prod. Sci. 56, 2015, pg. 153-168. Accessed at: http://dx.doi.org/10.1071/AN15386.
[68] Canadian Cattlemen's Association, "Beef Industry Strategies for Reducing Greenhouse Gases and Building the Green Economy." Accessed at: http://www.cattle.ca/assets/0c1041cd87/Strategies-for-Reducing-Greenhouse-Gases-from-Beef-Production-in-Canada-26.07.16.pdf.
[69] FAO, "GHG Emissions Intensity of Canadian Livestock." Accessed at: http://www.fao.org/3/a-i3437e.pdf.

GHG Emissions from the Meat and Dairy Supply Chain

Meat and dairy production has received unprecedented media attention recently, due to its contribution to GHG emissions and climate change. GRAIN (2018) released a report claiming that the combined supply chain emissions from the top five largest dairy and meat processors (i.e., Brazil's JBS, New Zealand's Fonterra, Dairy Farmers of America, Tyson Foods, and Cargill) were higher than the emissions from Exxon-Mobil (577 Mt), Shell (508 Mt), or BP (448 Mt) put together. This report, together with claims made by various op-eds, internationally and in Canada, and the recently published EAT Lancet Report,[70] that the earth could be saved from climate change if we all stopped eating meat, has initiated an intense debate.[71] Increasingly, scientists and farmers are providing counter arguments, focusing on why certain grazing practices are necessary to sequester more carbon in grasslands and to improve biodiversity. The major difference between the arguments provided by the sector and the GRAIN study is that the study includes GHG emissions across the entire supply chain, including processing, transportation, warehousing and other activities. This results in higher than necessary estimates. It does not, however, focus on cattle rearing activities and excludes the GHG savings associated with keeping grasslands from being converted to crop production.

From Policies and Practices: Improving the Environmental Impacts of Agriculture

Because of the strong linkages between agricultural production and the environment, efforts to achieve clean growth and a zero-carbon future require measures to mitigate climate change and offset any negative environmental impacts of agricultural production on soil, water, air, wildlife habitat and biodiversity (i.e. externalities).

Agricultural producers have long understood this fact. They know that in order to ensure the long-term sustainability and profitability of their land, they need to be good stewards. By adopting BMPs to increase soil organic matter, optimize nitrogen and pesticide use, minimize GHG emissions, reduce manure, pesticide and fertilizer run-off and prevent soil erosion, producers can do their part. However, this requires knowledge and awareness, and investments in innovations and new technologies. There are, however, costs involved and foregone revenues. And while producers can benefit from these actions themselves, society also benefits. Producers are not necessarily rewarded through the marketplace, since the environmental benefits (i.e. externalities) are not monetized for producers through market prices. This is a market failure. Thus, there is a role for government, through various incentives, along with voluntary actions and

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[70] EAT-Lancet, "Summary Report of the EAT-Lancet Commission," January 2019. Accessed at: https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(18)33179-9.pdf?utm_campaign=tleat19&utm_source=HubPage.

[71] Jennifer Blair, "Cattle Aren't Actually Killing the Planet," March 2, 2018. Accessed at: https://www.albertafarmexpress.ca/2018/03/02/cattle-arent-actually-killing-the-planet-says-vegetarian-rancher/.

industry-led initiatives, to help mitigate the environmental impacts of agriculture while ensuring long term growth and prosperity, an aim of "clean growth."

Federal and Provincial Government Policies

Canada's strong commitment to climate change mitigation and environmental improvement was made clear with the development of its *Pan-Canadian Framework on Clean Growth and Climate* strategy.[72] This was an agreement signed between federal, provincial and territorial governments in 2016 which provides an overarching framework for clean growth. This, together with Canada's commitments to the *UN Sustainable Development Goals,* signals that Canada is on the right road to future environmental, social and economic sustainability.[73]

The federal and provincial governments have several policy instruments available to them for ensuring the agricultural sector can produce sustainably and achieve clean growth. These include: moral suasion, regulations, and economic instruments.[74] In practice, usually a mix of the three is used. Figure 16 lists several examples of government programs in use today.

Figure 16: Federal and Provincial Government and Voluntary and Industry Initiatives

GOVERNMENT	VOLUNTARY/INDUSTRY
National Environmental Farm Plans (EFPs)	Alternative Land Use Systems Canada (ALUS)
Agroecosystem Living Labs Approach (ALL)	Canadian Roundtable for Sustainable Crops (CRSC)
Beneficial Management Practices	Canadian Roundtable for Sustainable Beef (CRSB)
Ontario's Agricultural Soil Health and Conservation Strategy	4R Nutrient Stewardship
Alberta's On-Farm Stewardship (OFS) and Confined Feeding Operations (CFO)	Natural Capital Coalition
Alberta's Agricultural Carbon Offsets Program	Nature Conservancy of Canada; Ducks Unlimited Canada (DUC)

[72] "Pan Canadian Framework on Clean Growth and Climate Change," November 2016. Accessed at: https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/climate-change-plan.html.
[73] "Canada and the 2030 Sustainable development goals," pg. 3. Accessed at: https://international.gc.ca/world-monde/issues_development-enjeux_developpement/priorities-priorites/agenda-programme.aspx?lang=eng.
[74] A Weersink, "Policy Options to Account for the Environmental Costs and Benefits of Agriculture," Canadian Journal of Plant Pathology, September 2002.

Moral Suasion

Moral suasion has been used more extensively than other options in Canada and abroad to improve the environmental performance of agriculture.[75] This includes training and extension to increase farmers' awareness of the impact of their current farming practices on the environment, through information, knowledge and education. Often moral suasion will be combined with financial incentives to increase farmers' participation, given the voluntary nature of these programs. The national Environmental Farm Plan (EFP) is an example of such a program (See Annex A).

Public and private Research and Development (R&D) investments have played a key role in the past for developing the knowledge about BMPs and disseminating this information to farmers through extension and outreach programs.

Regulations

Regulations are also used often to promote environmental performance and address the negative externalities associated with agricultural production. Regulations involve a government regulator mandating socially desirable behaviour into law using enforcement mechanisms or fines.[76] As an example, standards are used to bring about environmental improvements that either impose limits (performance-based) on behaviour or dictate operating practices (design-based) that will not harm the environment. These types of measures are popular for their simplicity, but require substantial administrative resources to enforce, and hence are less efficient than some other options.

Market-based Economic Instruments

The third type of policy option available to the government includes economic instruments, which provide incentives for producers to modify their behaviour.[77] This is done through subsidies, to help offset the cost of compliance, or charging taxes that raise the cost of the detrimental behaviour.

Another example are tradeable permits, such as Cap and Trade or carbon offset programs introduced to reduce carbon, sulphur dioxide and other harmful emissions and promote environmental performance. Alberta's Carbon Offset Program is an example of this type of program (see Annex A). These types of economic instruments are all considered very efficient options for achieving environmental objectives, as they are usually low-cost options with few unintended consequences.

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[75] Ibid, pg. 268.
[76] Ibid, pg. 269.
[77] Ibid.

Cross-compliance

Cross-compliance programs are another example of an economic instrument used to incent farmers to improve their environmental performance.[78] They tie direct payments for farm income support to basic standards of practice, which can achieve agri-environmental goals. They have been considered an option in Canada in the past, but have never been implemented, apart from in the Quebec hog sector.[79] However, they have been implemented quite successfully in the U.S., while less so in the EU. Annex B provides a description and evaluation of the performance of these U.S. and EU cross-compliance programs. The feasibility of cross-compliance programs within a Canadian context have been studied and are considered too expensive and not well targeted.

Cross-Compliance in Canada?

Rude and Weersink (2018) analysed the feasibility and effectiveness of a cross-compliance option by looking at current Business Risk Management (BRM) programs (*Agri-Invest* in particular, since there are no other legislative routes to allow for the implementation of cross-compliance other than through *Agri-Invest* (under GF2)).[80] They analysed three potential options where cross-compliance might be used to target environmental improvements and considered the effectiveness of these options by measuring 1) program participation, 2) compliance with regulations, 3) environmental performance and 4) welfare effects.

The authors argued that for these cross-compliance options, the amount of leverage the regulator has over the environmental impact depends on the level of the agricultural payment (i.e. the carrot), rather than the value of the environmental benefit. Hence, the incentives to participate would be very low. Also, the provisions of the income support programs limit the degree to which targeting of the environmental problem is possible and make it difficult to target specific individuals and regions. In addition, cross-compliance violates Tinbergen's (1952) rule for efficiency in which the number of policy instruments should equal the number of goals. So, the authors conclude that for cross-compliance to be more successful than individual environmental programs it must be targeted by taking account of the spatial, temporal and technological heterogeneity of environmental problems. It would also probably require a bigger incentive and better data to be successfully implemented, monitored and evaluated.[81] These are similar to the findings of Boxall with regards to the Alberta Stewardship programs.[82]

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[78] J. Rude and A. Weersink, "The Potential for Cross-Compliance in Canadian Agricultural Policy: Linking Environmental Goals with Business Risk Management Programs," Canadian Journal of Agricultural Economics, 66, 2018, pg. 359-377.
[79] J. Rude and A. Weersink, pg. 360.
[80] Ibid.
[81] Ibid. pg. 364.
[82] P. Boxhall, "Evaluation of Agri-Environmental Programs: Can We Determine If We Grew Forward in an Environmentally Friendly Way?," Canadian Journal of Agricultural Economics, 66, 2018, pg. 184.

Do Canada's Current Set of BRM Programs Negatively Impact the Environment?

Canada's current suite of direct program payments for farm income support, called Business Risk management (BRM) programs, provide whole-farm support to net income. The goal of these programs is to stabilize farm income through deficiency-type payments (*Agri-Stability*), by insuring against production and yield losses and disasters (*Agri-Insure and Agri-Recovery*) and by providing incentives to invest (*Agri-Invest*). They are cost-shared between federal and provincial/territorial governments and amounted to about $2 billion per year between 2011 and 2016.[83]

There are studies that suggest that direct income support to farmers can have negative effects on the environment. Rude (2018) argued that these programs have had a minimal negative incremental effect on the environment. This is because Canada's farm support programs are delivered as a whole-farm approach rather than commodity specific, and hence do not distort the enterprise mix, or lead to more intensive production systems or increased overall scale of total production which could have negative environmental effects.[84] Rude argued that *Agri-Insure,* being Canada's crop insurance program, has had some effect on crop choice and rotation but does little to induce marginal land into production.[85] Rude and Kerr (2013) found that *Agri- Stability*, which is a deficiency payment type program, has had some impact on input use, leading to modest increases in crop production. Recent reforms to this program have made it more production neutral.[86] While *AgriStability* participation rates are highest among hog producers, there is no evidence to suggest that this program creates incentives to consolidate into concentrated animal feeding operations. Rather, the consolidation of smaller farms into larger intensive units has been driven by market forces and technological change and not BRM programming.[87]

Extension

In summary, the Canadian government makes use of several policy instruments to promote environmental performance in agriculture including agri-environmental regulations, standards, investment in R&D, extension training and outreach, cost-sharing and direct payments to farmers. In this way, agricultural policies, particularly those funded through the Canadian Agricultural Partnership (CAP) five-year framework are targeting environmental performance, which should help the sector contribute to clean growth.[88]

[83] James Rude, "Business Risk Management Programs and the Environment," Paper Prepared for CAPI, 2018, pg. 3. Accessed at: https://capi-icpa.ca/wp-content/uploads/2018/09/2018-09-CAPI-BusinessRiskMgmntProgramsEnviro_JRude-1.pdf.
[84] Ibid.
[85] Ibid.
[86] Ibid, pg. 5.
[87] J. Rude and A. Weersink, pg. 374.
[88] Agriculture and Agri-food Canada, Press Release, "Canadian Agricultural Partnerships," April 3, 2018. Accessed at: https://www.canada.ca/en/agriculture-agri-food/news/2018/04/canadian-agricultural-partnership-a-cornerstone-for-the-continued-growth-of-a-key-economic-sector.html.

Voluntary and Industry-Led Policies

There are also other types of initiatives introduced by industry or through NGOs that have been effective in addressing the negative externalities associated with agriculture (Figure 16). Many of these are voluntary initiatives that are funded through donations, philanthropic foundations or community conservation societies. Examples include Ducks Unlimited Canada, Alternative Land Use Systems Canada (ALUS), funded through the Weston Foundation, and the 4R Nutrient Stewardship program, introduced by Fertilizer Canada (see Annex C). These programs tend to be relatively inexpensive to implement, effective due to their community targeting, but often result in free-rider problems, where some producers benefit without making any effort.

Industry-led initiatives aimed at improving sustainable agricultural production include industry investments in R&D through check-offs, public-private partnerships, research clusters, domestic and international collaboration on climate change mitigation, sustainability standards and certification, investments in scientific measuring, data and monitoring, and community-sponsored and individual farm investments in sustainable production practices such as carbon sequestration, conservation and no-till tillage and grazing land management. For a more detailed description of these types of initiatives see Annex C.

Finally, industry has also made efforts to promote sustainable production practices through the development of new markets for sustainable products that can be rewarded with price premiums. However, this requires information and transparency for consumers, so they will trust the products. This can only be done if the products are certified by third parties, and labelled as such, so the consumers who are willing to pay more for these characteristics will believe them. Examples of such industry initiatives include those being implemented by the Canadian Roundtable for Sustainable Beef (CRSB) and the Canadian Roundtable for Sustainable Crops (CRSC) wherein mechanisms are being developed for delivering sustainable products to consumers.

The examples provided here are just some of the options available to governments and industry for encouraging environmental performance in agriculture. These, together with new technologies and innovations being developed and adopted will help ensure Canadian agriculture can achieve clean growth in the future. A further discussion of some of these new technologies and innovations that are emerging on the horizon are presented below.

Innovation, New Technologies and the Adoption of Innovative Practices

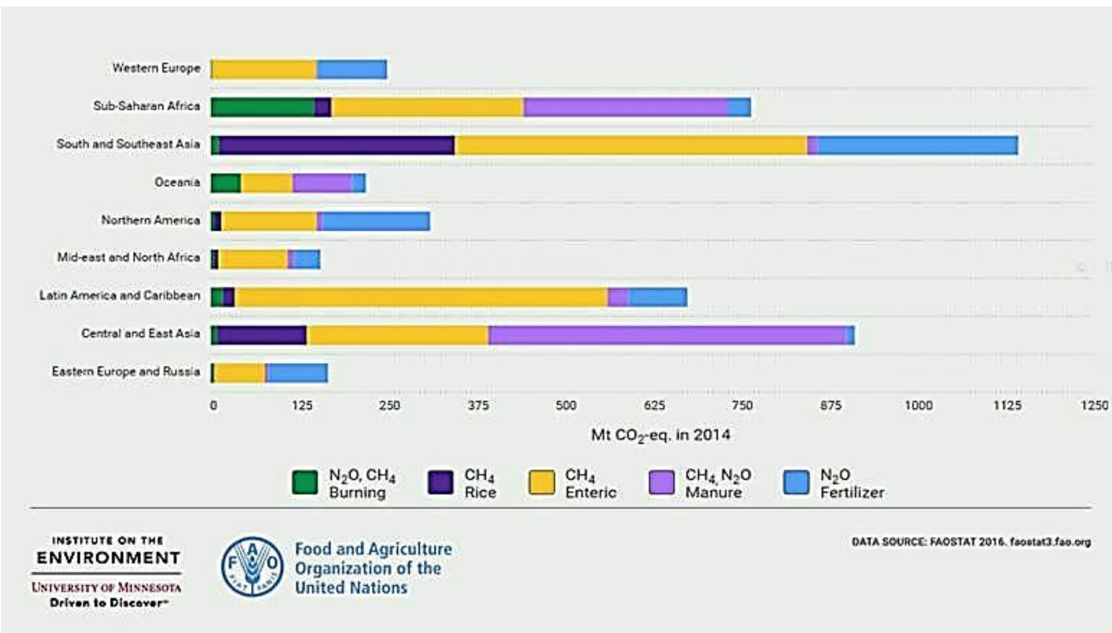
Soil and Carbon Sequestration

In Canadian agriculture, real gains in C sequestration have been mostly the result of innovations in farm management practices and in plant and animal genetics. This includes improved grazing practices, soil management, manure management, improved animal genetics and feeding efficiency and increased crop yields. Most of these improvements have been the result of voluntary actions made to improve farm profitability. An example is better animal feeding regimes that increase efficiency and reduce the cost of animal rearing. Another example is the development of zero-till technology which originally aimed to maintain soil moisture and solve chronic drought problems in the prairies. However, it also led to lower fuel and labour costs and improved soil quality and sequestration.

Animal Agriculture

The chart below (Figure 17) provides a comparison of sources of GHG emissions from livestock production, excluding direct CO_2 emissions from fossil fuel combustion. It is clear that on a continental basis, the contribution of Western Europe and North America to emissions of CH_4 from enteric fermentation and manure, and N_2O emissions from manure, is relatively small compared to other regions, despite the fact that North America is a large livestock producing region. This reflects the impacts of genetic improvements, animal health and increased feeding efficiency in livestock production in North America. The knowledge and technology that has contributed to these could easily be both transferred to other continents to contribute to an improvement in the global commons.

Figure 17: Comparison of GHG emission sources from livestock production[89]



Soil Microbiome

Developments in the knowledge of the soil microbiome are helping the sector achieve clean growth. New knowledge around soil, a complex living biome with direct links through highly conserved genes to human and animal microbiomes, provides a foundation for a microbe-plant-animal-human health connection. One of the positive outcomes of understanding these complex

[89] FAO, "Comparison of GHG emission sources from livestock production." Accessed at: http://www.fao.org/3/a-i3437e.pdf.

relations is highlighting the potential role of soils in mitigating climate change. Building soil organic matter, as suggested by the 4/1000 initiative, could remove 14 giga tonnes of CO_2 from the atmosphere annually.[90] This has the potential to reduce the CO_2 in the atmosphere below the current levels while developing more fertile, resilient soils to feed people for years to come and keep forests intact.

Plant Characteristics

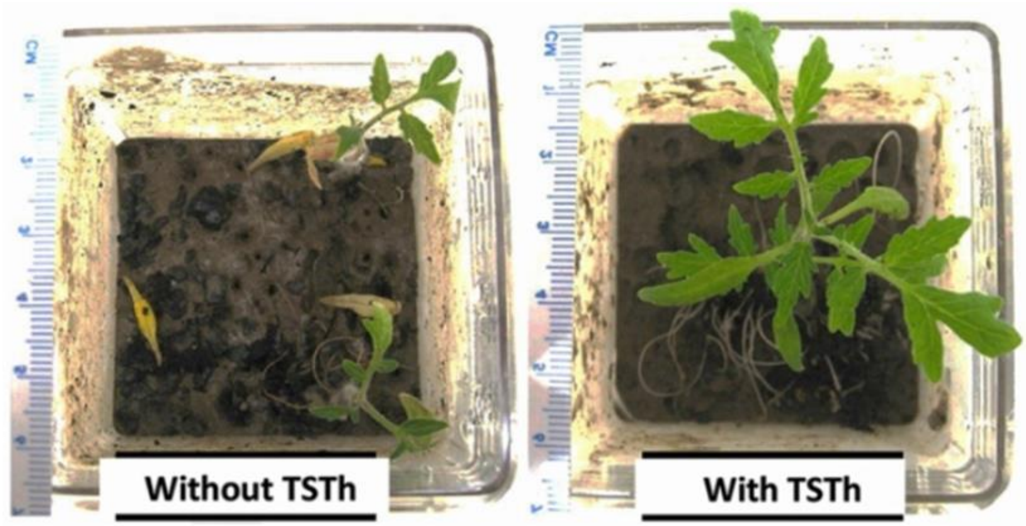
Efforts to mitigate Climate Change are increasingly focusing on plants as well. Advanced Research Projects Agency-Energy (arap-e), a United States government agency tasked with promoting and funding R&D in advanced energy, has a program aptly entitled ROOTS.[91] The program intends to address the impacts of agricultural production on soil quality, increased fertilizer use and CO_2 emissions. The objective of the program is "…to develop crops that enable a 50% increase in carbon deposition depth and accumulation, a 50% decrease in fertilizer N_2O emissions, and a 25% increase in water productivity. Taken over the 160 million hectares of actively managed U.S. cropland, such advances could mitigate about 10% of total U.S. GHGs annually over a multi-decade period, while also improving the climate resiliency of U.S. agricultural production."[92]

Likewise, the Canadian Space Agency recently announced a grant program of over $800 million for Canadian Universities to lead research on sustainable agriculture.[93] SALK Institute in California has a program called Harnessing Plants for the Future, which is again focusing on the development of plants which will remove more CO_2 from the atmosphere, by storing carbon stably in roots (or root systems) deep in the soil.[94] The Project aims to increase environmental stress tolerance of plants, eliminate the need for tilling, and reduce fertilizer use to feed the world sustainably.

Clearly, there are questions about applicability of some of these technologies to food crops without sacrificing yields, or the potential returns to some very expensive research justifying the investment. However, the quest continues to produce solutions. Dr. Susan Kaminskyj, a professor of biology at the University of Saskatchewan, discovered a fungus living in dandelions that gives then the ability to grow in coarse tailings, which were stripped of all plant nutrients and still retain a residue of petrochemicals.[95] Not only that, but the plants can also clean up the coarse tailings it grows in, opening up the potential for food crops to grow in degraded soils, but also to rehabilitate those soils in the process (Figure 18).

[90] 4 per 1000 Initiative. Accessed at: https://www.4p1000.org/.
[91] Arap-e ROOTS. Accessed at: https://arpa-e.energy.gov/?q=arpa-e-programs/roots.
[92] Ibid.
[93] Canadian Space Agency. Accessed at: http://www.asc-csa.gc.ca/eng/Default.asp.
[94] Salk Institute, "Harnessing Plants Initiative." Accessed at: https://www.salk.edu/harnessing-plants-initiative/.
[95] S. Kaminsky, U. of Saskatchewan, "Dandelions," Accessed at: https://www.cbc.ca/news/canada/saskatoon/dandelion-oilsands-1.4369041.

Figure 18: Untreated tomato seedlings compared with seedlings treated with TSTh20-1[96]



Untreated tomato seedlings compared with seedlings treated with TSTh20-1 fungus after growing for two weeks on coarse tailings. (Susan Kaminskyj)

Grasslands and Grazing

Another area of innovation is in the intersection of plant and animal agriculture: on grasslands and grazing practices. Temperate grasslands are key to the survival of many species of mammals, plants, birds, amphibians, reptiles, and insects which are reportedly being lost at annual rates greater than the loss of biodiversity in the Amazon Rainforest.[97] "Cattle, in a sense, can take on the ecological role of the bison, which once roamed the temperate grasslands throughout North America. Bison grazed and trampled the prairie, leaving behind a tapestry of vegetation that was ideal for other species found there. Ranchers can achieve comparable results by managing their cattle grazing in ways that produce similar landscapes."[98]

Grazing and grasslands also serve a role in C sequestration. A study on removing animals from US agriculture indicated that to meet the food/nutrient requirements of the US population, the production of crops, particularly grains and legumes, would have to increase significantly.[99] This would require converting grasslands and pastures to cropland which would release CO_2 emissions, thereby offsetting some of the reductions in GHG emissions associated with removing animals from the system. Net emissions from agriculture would be around 28% which is equal to a 2.6% reduction in total US GHG emissions. In addition, there would be a potential loss of

[96] S. Kaminsky, U. of Saskatchewan, "Untreated tomato seedlings compared with seedlings treated with TSTh20-1." Accessed at: https://www.cbc.ca/news/canada/saskatoon/dandelion-oilsands-1.4369041.
[97] WWF, Living Planet Report Canada, 2017. Accessed at: http://www.wwf.ca/newsroom/reports/lprc.cfm.
[98] J. Pittman, "How cattle ranching can help preserve species at risk in Canada's grasslands," Canadian Geographic, July 24, 2018.
[99] White, R.R. and M.B. Hall, "Nutritional and greenhouse gas impacts of removing animals from US agriculture," PNAS, November 13, 2017.

grassland and biodiversity. A recent University of Wisconsin study that examined the impact of the nearly 30,000 km^2 cropland expansion in the US during the period of 2008-2012 and concluded that this expansion led to a nearly 30 megatonnes/year increase in carbon emissions.[100] Moreover, the study indicated that "… 87% of emissions resulted from cropland expansion onto grasslands where soil carbon was the largest source of emitted carbon.

A recent study by the WWF (2016) argued that approximately 70% of the grasslands in Western Canada had already been converted into cropland since colonization.[101] And in 2015 alone, an additional 2.78% of the prairie grasslands were converted, contributing to greater biodiversity and soil carbon loss. This appears to be a longer term trend to conversion of native grasslands at a rate that far outstrips the collective action of landowners, cattle producers, land trusts and governments to conserve grasslands. This suggests there could be significant benefits for collaboration among producers raising cattle on native grasslands, conservationists who want to conserve biodiversity on the prairies by conserving native grasslands and those parties working to maintain and enhance stored $C0_2$ by conserving both.

Additional research in Europe found that converting croplands, with much higher yields than the prairies, back to grassland would not necessarily improve C-sequestration.[102] This emphasizes the critical role of local agronomic conditions in identifying potential solutions. The significance of this research is to show the importance of soils and land use choices on clean growth opportunities for agriculture.

The Way Forward

How will agriculture reduce its GHG emissions and increase its ability to sink carbon? The following approaches are our suggestions to be used for such a task.

In terms of government policies and initiatives, the options consist of regulations, economic instruments, moral suasion, to name a few. However, the high cost of implementing and enforcing environmental regulations for agricultural producers often makes the effectiveness and desirability of these measures questionable. Economic instruments, such as taxes imposed on undesirable actions, such as pollution (or subsidies to encourage desirable actions) target only actions and therefore cannot always guarantee outcomes. For example, the EU's experience with green subsidies to farmers for environmental practices, demonstrates this weakness.[103] In addition, the application of taxes and economic tools generally remain at the will of political governments. The examples of taxes in the U.S., Australia, and various Canadian provinces make clear the frailness of this and suggest that market-based solutions might be better instruments of choice for incenting farmers to improve environmental outcomes.

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[100] S. Spawn, T J. Lark, Holly K Gibbs, "US Cropland Expansion Released 115 Million Tons of Carbon (2008-2012)," Summary of research presented at the America's Grasslands Conference 11/15/2017, Fort Worth, TX.

[101] WWF, The Living Planet Report Canada: A National Look at Wildlife Loss, 2017, pg. 42.

[102] Paul Gosling, Christopher van der Gast & Gary D. Bending, "Converting highly productive arable cropland in Europe to grassland: a poor candidate for carbon sequestration," Scientific Reports, September 2017.

[103] See Annex C in Full Report for a description of the EU Green Programs and their effects.

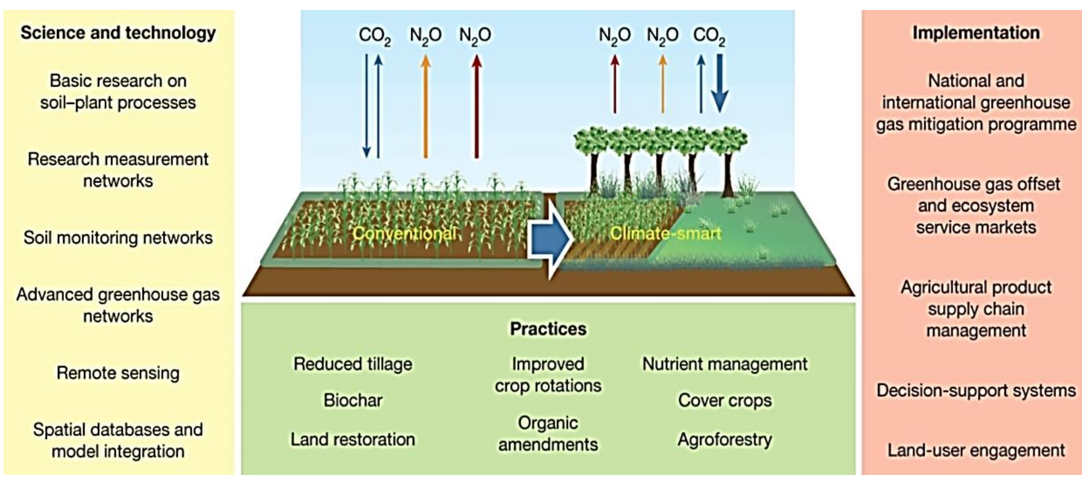
Community-based actions and initiatives promote voluntary changes in practices through motivating and enabling practitioners on the ground. However, these initiatives will only work if the information is available and shared in an open platform and the required changes do not create an economic loss for the producers.

Policies and corrective measures are usually introduced after the damage is done. A better option is preventing the damage before it occurs, and this could be achieved by rewarding practices that avoid damage. The proponents of REDD, a UN Programme that supports national and international implementation of reducing emissions from deforestation and degradation, are pushing forward the idea of giving credits to leaving forests and grasslands untouched.[104]

Taking care of the global commons will require re-inventing the concept of comparative advantage that takes into account environmental externalities. This will require the development of standards, metrics and transparent systems that can be used internationally for certification and labeling of environmental foot print of all commodities. This will require countries recognize and enforce them as a part of international trading practices.

The following chart by Paustian summarizes the components of clean growth in agriculture and delineates the process needed to move forward (Figure 19). This process relies on innovations in three areas more than anything else: science and technology, farm practices and implementation.

Figure 19: Components of Clean Growth in Agriculture[105]



The next steps are not only about developing and adopting the technologies and practices that could move the sector towards carbon neutrality, but also about certifying, labelling, and selling the products at prices that covers the cost of carbon neutrality. Raising awareness is a key to motivating technology adoption. For example, a recent study indicates that producers who are concerned about the emissions produced by their cattle are willing to pay for genomic selection

[104] Reducing Emissions from Deforestation and Degradation (REDD). Accessed at: http://www.un-redd.org/.
[105] K. Paustian et al, "Components of Clean Growth in Agriculture," Nature 532, 2016, pg. 49-57.

for feeding efficiency and reduced methane emissions.[106] The question becomes how do we align private and public benefits to encourage technology adoption?

Implementation of new technologies and practices will require a major overhaul in national and international policies and approaches to create enough incentives for them to be adopted at a scale that could maintain the ability of the sector to produce while contributing to climate change mitigation. Getting them to jointly produce real impacts is where the real challenge lies.

What is needed is a community of experts and practitioners to link many of the challenges in adopting clean growth: aligning private and public benefits to boost awareness and the adoption of new technologies, present suggestions to existing national and international policies and initiatives with sufficient incentives for them to be adopted. Essentially this network would integrate science and policy research with industry and business practices and provide policy, innovation, and technology suggestions that would be applicable at the micro-level while also creating a real impact on a national and international scale. Other recent initiatives using this model have proven successful for introducing transformative forces for climate change: this includes the Transition Accelerator organization.[107]
[108]

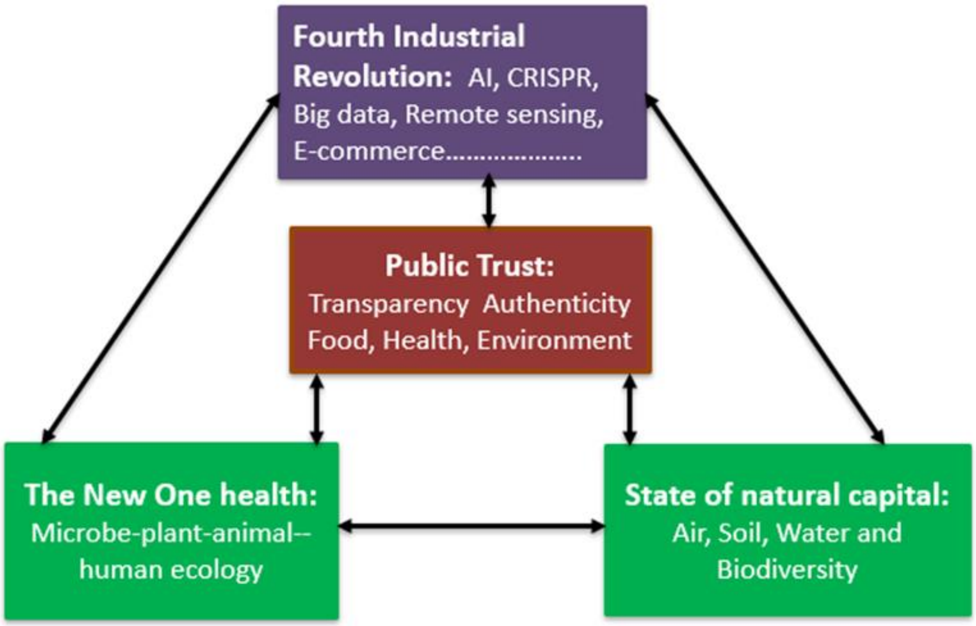
It is imperative to move beyond traditional knowledge dissemination. This community of experts would bring together and encourage collaboration between physical scientists (plant, soil, animal); social scientists (policy, economics, business); and practitioners, farmers, and ranchers to adopt beneficial practices and disseminate knowledge, with the primary goal of making the knowledge accessible to a wide audience and applicable to different circumstances.

[106] G. Hailu, pg. 9.

[107] This proposed Network is similar to a recently introduced organization called "the Transition Accelerator", which "convenes researchers, industry experts and civil society leaders to envision, chart and pilot game-changing pathways to address climate change that will help Canadians thrive into the 21st century and beyond". Accessed at: https://www.transitionaccelerator.ca/

[108] This proposed Network is similar to a recently introduced organization called "the Transition Accelerator", which "convenes researchers, industry experts and civil society leaders to envision, chart and pilot game-changing pathways to address climate change that will help Canadians thrive into the 21st century and beyond". Accessed at: https://www.transitionaccelerator.ca/

Figure 20: The road to clean growth: Integration of science and policy research and industry practices[109]



Investments to Target Clean Growth in Agriculture

Implementation of new technologies and practices will require a major overhaul in national and international policies and approaches to create enough incentives for them to be adopted at a scale that could maintain the ability of the sector to produce while contributing to climate change mitigation. This is where the real challenge lies: to be able to increase agricultural production while reducing sectoral GHG emissions.

Investments by both public and private sectors could go some real distance to encouraging positive action in this direction. Five immediate action areas would be assisted by increased investment, new programs and other mechanisms.

(1) Investment in policy initiatives in the agriculture and food production space to prioritize target areas for environmental improvement

This Executive Report demonstrates that agriculture and food production impacts at least five distinct areas of environmental outcomes—those affecting water, biodiversity, air quality, soil health and greenhouse gas emissions. As a recent CAPI dialogue revealed,[110] it is rare that the

[109] "The road to clean growth: Integration of science and policy research and industry practices," CAPI Presentation, 2018.
[110] "Optimizing Land Use for Sustainable Growth: a CAPI Dialogue," Calgary, February 21-22, 2019. Available at: https://capi-icpa.ca/events/optimizing-land-use-for-sustainable-growth-a-capi-dialogue-february-21-22-2019/

agriculture-environment dialogue yields clearly articulated priorities for outcomes. Is one to prioritize those which are most important to the planet and to Canada, or those which are most achievable and most likely to be taken up by agriculture and food producers in Canada? Too often experts, practitioners or even the general public speak only in general terms of improving agriculture's environmental performance.

Investments are needed that specifically encourage dialogue for establishing consensus around the environmental outcomes and targets that need to be the focus of strategic efforts. Controlling GHG emissions a of course a top priority. However, how much focus should be placed on other positive environmental outcomes that can be achieved easily or at the lowest cost? This dialogue needs to happen to bring focus to the direction that must be taken to enhance the provision of positive environmental goods and services from agriculture

(2) Investment in technological advances and implementation of beneficial management practices that yield improved environmental outcomes for specific environmental goals

Where it has been determined that one of the environmental outcomes should be advanced above others in agriculture and food production, then new investment in existing or new technologies facilitating BMPs could assist either in the development of the BMP or its scale-up.

The most obvious example of this is in the scale-up of 4R fertilizer technology and techniques. 4R fertilizer technology not only improves profitability for farmers because they can apply less fertilizer to their crops while maintaining or even enhancing yields, but also leads to less nutrient loss to ground water, reducing water quality deterioration, and less loss to the air, reducing climate change. Studies show however, that the uptake of this technology with "win-win" benefits has had a relatively slow scale-up amongst Canadian producers. In 2014, there were 500,000 acres under 4R Nutrient Stewardship, and this rose to only 2.2 million acres by 2016. With Fertilizer Canada's goal of 20 million acres to be covered by 2020, there is still a lot of work to do. Research shows that by applying the 4Rs to corn production in Ontario for example, can reduce GHG emissions by an average 50%, reduce phosphorous losses through run-off by 60%, and increase yields by nearly 20%. Currently, only 68% of farmers in Ontario use some form of 4Rs. By raising adoption rates to 75%, there could be a reduction of GHGs by 540 kg CO2Eq/ha/yr.[111] With 2.2 million ha of Ontario cropland in corn, this translates into an additional 61,600 ha covered by 4Rs and an additional .03 Mt of CO2eq emission reductions.

Other examples of new technologies that could reap large environmental benefits or significantly reduce GHG emissions through widespread adoption and scale-up, include precision agriculture, new crop varieties that sequester carbon, better crop rotation and more cover crops and no-till. For example, by adding pulses into the crop rotation (oilseed-pulse-durum wheat) on the Prairies, has been shown to reduce the carbon footprint of cropping by 29%, relative to a non-pulse crop

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[111] Fertilizer Canada, "Key Findings of the Canadian 4R Research Network", 2018. Accessed at: https://fertilizercanada-ksiu6qbsd.netdna-ssl.com/wp-content/uploads/2018/08/fc_4R-key-findings2018_en_vf-digital.pdf

rotation (ie. cereal-cereal-durum wheat). How this can be changed for better economic and environmental results is a question well worth asking.[112]

(3) Investment in technological advances and implementation of beneficial management practices that yield improved environmental outcomes for different regions of agricultural production

Where it has been determined that a specific region of Canada should be targeted for improved environmental outcomes for regional agriculture and food production, then new investment for producers or their associations could be negotiated to improve the general uptake of BMPs or nascent technology that advance environmental outcomes in the region.

For example, an important environmental concern in Prairie agriculture are PM2.5 emissions and the human health concerns they raise while in Central Canadian agriculture GHG emissions or water quality are bigger concerns. Stakeholders targeting these regional priorities could well engage local, provincial and federal governments for policy innovation, while also engaging producer associations, producers themselves and non-governmental organizations to identify and then roll-out through government policy or market incentives, the BMPs or other measures to bring about behavioural changes to advance the desired environmental outcomes in the region.

(4) Investment in scaling-up of known technologies that will yield positive environmental outcomes

Similar to (2) above, stakeholders may have already identified a technology or project that they feel will yield a particular environmental benefit as it relates to the field of agriculture and food production.

An example might be an organization's goal of reducing GHG emissions by the reduction of the use of fossil fuels by increasing the efficiency of petroleum engines or the replacement of them by electric engines. This objective, although somewhat narrow in achieving environmental benefits in the agriculture sector, could be championed through investment in the development of power technologies that would be available to the agriculture sector or by assistance in the uptake of such technology by producers.

(5) Investment in the creation of communities of interest that will generate new and transferable knowledge and build support for increasing agricultural productivity and environmental goods and services ("win-win" communities of advancement)

Perhaps what is needed most in the area are new concepts and constructs of leadership in imagining "win-win", "agriculture-environment", "profitability-sustainability" solutions. What we need is a community of experts and practitioners, a NETWORK of thought leaders, who can come together to link many of the challenges in adopting clean growth, like aligning private and

[112] CAPI-AgWest Bio Workshop, Presentation to Saskatoon Barton Forward "Growth, Innovation and Sustainability for Pulse Crops", December 2017.

public benefits to boost awareness and the adoption of new technologies, and then presenting suggestions to existing national and international policies and initiatives with sufficient incentives for them to be adopted. Essentially this NETWORK would integrate science and policy research with industry and business practices and provide policy, innovation, and technology suggestions that would be applicable at the micro-level while also creating a real impact on a national and international scale. Other recent initiatives using this model have proven successful for introducing transformative forces for climate change: this includes the Transition Accelerator organization.[113] [114]

In the process towards sustainable growth, quality growth, clean growth in agriculture, three main steps are required:

(1) Stage 1 - Discovery (science, innovation and technology);
(2) Stage 2 - Market Availability (crafting beneficial management practices), and
(3) Stage 3 - Implementation (scalability and widespread adoption). [115]

We believe that this NETWORK can engage in initiatives that focus on a holistic approach to clean growth, awareness and education, and help put knowledge gained into practice to encourage sustainable agriculture and growth.

Beyond the traditional dissemination of knowledge, the promotion of new technologies and innovations, and support to farmers and producers will only encourage further collaboration and developments in the goal of clean growth. The focus should be on optimizing land use in Canada, while maintaining the sector's competitiveness, by bringing a transdisciplinary group of experts together to both help prioritize goals to clean growth in agriculture, as well as identify the investments needed to achieve them. In this way, collaboration between public and private stakeholders, industry, community and voluntary organizations can work towards ensuring the sector can optimize growth for a sustainable future.

[113] This proposed Network is similar to a recently introduced organization called "the Transition Accelerator", which "convenes researchers, industry experts and civil society leaders to envision, chart and pilot game-changing pathways to address climate change that will help Canadians thrive into the 21st century and beyond". Accessed at: https://www.transitionaccelerator.ca/
[114] This proposed Network is similar to a recently introduced organization called "the Transition Accelerator", which "convenes researchers, industry experts and civil society leaders to envision, chart and pilot game-changing pathways to address climate change that will help Canadians thrive into the 21st century and beyond". Accessed at: https://www.transitionaccelerator.ca/
[115] The Transition Accelerator organization describes similar steps as part of its process.

Annexes

Annex A: Government Programs Promoting Environmental Performance in the Canadian Agriculture Sector

• **The National Environmental Farm Plan (EFP)**, funded and delivered at the federal-provincial- territorial levels, EFPs provide a voluntary, confidential, whole-farm environmental assessment tool to help individual farmers and ranchers identify on-farm environmental risks which together with an action plan can improve environmental outcomes.[116] Early EFP's were being encouraged in Ontario and Quebec in the 1990s, and they soon spread to other provinces and were implemented across Canada by 2005 under the federal government's Agricultural Policy Framework (APF). The APF defined a set of nationally consistent principles and program elements.[117] EFP's are delivered provincially and are tailored to individual provinces. Over the past 20 years, the EFP has proven its success as a model that spreads awareness and drives the process through environmental education, practical and proven best management practices, regulations and cost-sharing incentives.[118] As of 2011, 35% of Canadian farmers and ranchers had completed EFPs making it the most widely used environmental program in Canadian Agriculture.[119] There are regional differences, however, with recent surveys showing that 72% of Quebec farms, 53% of Maritime farms and 43% of Ontario farms had adopted an EFP.[120] Uptake was lower on the Prairies, but since has been increasing. However, adoption is influenced by many factors, including farm type, size and provincial policies.
• **Agroecosystem Living Labs Approach (ALL)-** Agroecosystem Living Labs is a recently initiated innovative, integrated approach to agricultural research, bringing scientists, industry and farmers together to develop, test and monitor new technologies and practices on farms.[121] ALL is anticipated to accelerate both the development and adoption of beneficial management practices (BMPs). Minister McAulay recently offered to share this

[116] T. Hoppe, D. Haak, and J. Hewitt, "Farm Environmental Management," Environmental Sustainability of Canadian Agriculture, Agri-Environmental Indicators Reports Series- Report #4, 2016, pg. 39.
[117] Ibid, pg. 40.
[118] National Environmental Farm Plans, "About the Environmental Farm Plan." Accessed at: http://nationalefp.ca/about/environmental-farm-plan/.
[119] Statistics Canada, "Human Activity and the Environment: Agriculture in Canada," 2014, pg. 49. Accessed at: https://www150.statcan.gc.ca/n1/pub/16-201-x/16-201-x2014000-eng.htm.
[120] T. Hoppe, et al, pg. 41.
[121] "Canada Plays Leadership Role on Soil Conservation at G20 meeting in Argentina," July 30, 2018. Accessed at: https://www.newswire.ca/news-releases/canada-plays-leadership-role-on-soil-conservation-at-g20-meeting-in-argentina-689535061.html.

Canadian approach at the July 2018 meeting of G20 Agriculture ministers in South America.[122] The result will be more practical technologies and sustainable farming practices adopted more quickly by farmers around the world. Through these efforts, countries will be better able to address pressing environmental issues such as soil and water conservation, and climate change. Approaches such as this, along with barrier-free international agricultural trade, will go far in improving global food security.
• Beneficial Management Practices (BMPs)- BMP's are farming methods designed to improve farm productivity while also minimizing the potential negative impacts on the environment. BMP's are being implemented to manage manure, fertilizers and pesticides, and protect land and water resources and improve soil quality. They are adopted as part of the action plans associated with the EFPs described above. BMPs have been developed over time through collaborative research and application by federal and provincial government scientists, university researchers and industry who then test this knowledge with practitioners. Producers with an EFP in 2011 were more likely to have adopted a variety of BMPs according to recent surveys: 43% of Canadian farms with an EFP had fully implemented their plan's BMPs. Quebec farms in particular, reported the highest share of EFP farms (76%) which had also fully implemented BMPs in 2011.[123] Many factors can influence BMP adoption, including cost-savings, improved efficiency or regulations nevertheless, there is a clear trend toward increased adoption of BMPs in Canada, with or without an EFP.[124] As an example, **"conservation and no-till"** tillage practices are highly adopted BMPs that has contributed to improved soil quality and carbon sequestration on the Prairies. It is adopted to certain extent in other provinces as well but works better in dryland agriculture. Between 1991 and 2016, the amount of land under no-till, increased from 7% to 58% of total Canadian cropland, the percentage in Saskatchewan is 74%.[125] As an example, Dean Hubbard, an Alberta farmer, who switched to conservation tillage in 1995, has no fallow acres. His objectives were to improve soil moisture retention and increase soil organic matter (SOM), which increased in his fields from 1.5% to 3.5% over the period and he is convinced that there is potential for it to rise to 5% in the future.[126]

[122] Ibid.
[123] Statistics Canada, "Human Activity," pg. 49.
[124] T. Hoppe, pg. 41.
[125] Statistics Canada, Census of Agriculture 2016, "Seeding Decisions Harvest Opportunities for Canadian Farmers." Accessed at: https://www150.statcan.gc.ca/n1/pub/95-640-x/2016001/article/14813-eng.htm.
[126] Personal Notes from Canadian Federation of Agriculture Annual Meeting, June 2017.

• **Ontario's Agricultural Soil Health and Conservation Strategy**, announced in April 2018, provides a long-term framework that sets the vision, goals, and objectives for soil health and conservation in Ontario beginning this year through to 2030.[127] According to recent indicators, Ontario has experienced significant loss of soil organic carbon (SOC) and is subject to high risk of unsustainable soil erosion. This strategy will ensure technical expertise and make resources available to target Ontario soil quality issues by encouraging the adoption of BMPs that will promote SOC, reduce soil erosion, improve soil cover, by increasing crop rotations, conservation tillage and a shift towards more perennial forages away from annual crops.[128]
• **Alberta's On-Farm Stewardship (OFS) and Confined Feeding Operations (CFO) Programs**, were funded under the Growing Forward 2 (GF2) agri-food policy framework, as a part of federal-provincial cost-shared agri-environmental programs.[129] These programs focussed on water quality improvements through the adoption of BMPs at the individual farm level, providing financial incentives to producers who adopt BMPs for this purpose. Livestock producers are a significant component of agriculture in the province and hence there is greater risk of water quality issues. Some of the projects funded included riparian-area fencing, wetland restoration, shelterbelt establishment, improved pesticide and nutrient management etc. Under CFO programming, projects related to improved manure storage facilities, relocation of CFOs among others were funded. The program provided a share of implementation costs over the period 2013-17.[130] Boxall evaluated these programs and concluded that the program appeared to appropriately target funding and adoption in areas of the province that have higher levels of environmental risk. However, at the same time, have adopted BMPs that have more private than public benefits.[131] To do a better job of targeting public good benefits, Boxall argues that outcomes should be measured against program goals, which are to reduce environmental risks from agricultural production. This requires targeting efforts in a location-specific and even farm-specific level.[132]

[127] Ontario Ministry of Food, Agriculture and Rural Affairs, "New Horizons- Ontario's Soil Health and Conservation Strategy," April 2018. Accessed at: http://www.omafra.gov.on.ca/english/landuse/soilhealth.htm.
[128] Ibid.
[129] P.C. Boxhall, "Evaluation of Agri-Environmental Programs: Can We Determine if We Grew Forward in an Environmentally Friendly Way?," Canadian Journal of Agricultural Economics, 66, 2018, pg. 171-186.
[130] Ibid, pg. 175.
[131] Ibid, pg. 182.
[132] Ibid, pg. 185.

- **Alberta's Agricultural Carbon Offsets Program**- was originally introduced in 2007 as part of the Climate Change plan.[133] Its goal was to reduce Alberta emissions by 200 MT by 2050. In 2007, large industrial emitters were regulated and required to reduce their GHG emission intensities by 12%. They could achieve this through voluntary emission reductions or by buying carbon offset credits from others, which created the opportunity for farming community to change their practices to be able to earn carbon credits. The program was revamped in 2016 under the Climate Change leadership plan.[134] Agricultural producers and ranchers can participate in this carbon offset market as long as they follow approved protocols through adopting agricultural practices that create carbon credits. In this way they can trade in Alberta's carbon market and earn extra income while realizing long-term environmental benefits for their operations. Some of the protocols allowed under this program include conservation cropping (i.e. No-till, cover crops etc.), reductions in emissions from fed cattle, nitrous oxide emission reductions, biofuel production and usage, waste biomass, solar and wind micro-generation, beef low residual feed intake, biogas generation and energy efficiency. Since 2002, nearly of 13 Mt of CO2eq were voluntarily removed from the atmosphere in Alberta by improving agricultural practices, and offsets generated about $170 Million for farmers and aggregators (who monitor and put together contracts).[135]

[133] Alberta's Carbon Offset Program. Accessed at: https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/cl16248.
[134] Ibid.
[135] Susan Wood Bohm, "Carbon Policy: The Alberta Experience," presented at Banff, Alberta, November 2017.

Annex B: Voluntary and Industry-led Initiatives Promoting Environmental Performance in the Canadian Agriculture Sector

• **ALUS (alternative land use systems) Canada,** a Weston Family initiative was founded in 2006 and relaunched in 2016, as a community-based program that "sustains agriculture, wildlife and natural spaces for all Canadians-one acre at a time."[136] ALUS provides per-acre annual payments to participating farmers and ranchers to recognize their efforts in managing and maintaining projects on their land produce to cleaner air, cleaner water, and more biodiversity and other ecosystem services in their communities. In this way, ALUS helps farmers and ranchers restore wetlands, reforest, plant windbreaks, install riparian buffers, manage sustainable drainage systems, create pollinator habitat and establish other ecologically beneficial projects on their properties. ALUS Canada currently channels the funding provided by individuals, governments, foundations and corporations to more than 15,500 projects in 19 communities within six provinces (PEI, Quebec, Ontario, Manitoba, Saskatchewan and Alberta), while rapidly expanding within those provinces and to new provinces.[137]
• **Canadian Roundtable for Sustainable Crops (CRSC)** is a member-based organization that facilitates cross-commodity collaboration on sustainable agriculture issues and opportunities facing grains, oilseeds and pulse value chain participants.[138] Comprised of grower, industry, customer and environmental organizations, the CRSC is a national, industry-led forum developing and showcasing Canada's grains sustainability performance. Efforts are focussed on creating performance reporting based on credible data; researching and developing farm-level environmental, social, and economic sustainability measurements that are relevant to Canadian production practices; informing and engaging Canadian grain industry stakeholders on grains.[139]
• **Canadian Roundtable for Sustainable Beef (CRSB)-** The CRSB is a collaborative community of stakeholders devoted to advancing sustainability within the Canadian Beef industry and making the industry a global leader in sustainable beef production.[140] It does this through targeted efforts and the provision of government and industry investment in sustainable farming practices that are resilient to climate change. It aims to reduce the beef industry's environmental footprint, optimize carbon sequestration

[136] ALUS Canada. Accessed at: https://alus.ca/what-we-do/.
[137] Ibid.
[138] Canadian Roundtable on Sustainable Crops. Accessed at: http://sustainablecrops.ca/about.
[139] Ibid.
[140] Canadian Roundtable for Sustainable Beef. Accessed at: https://crsb.ca/.

	in grasslands and build a green economy while strategically increasing productivity, enhancing resiliency and mitigating emissions. This combined with the **National Beef Sustainability Assessment and Strategy (**released October 2016) will allow the industry to monitor progress and improvements across all three pillars of sustainability every 5-7 years through benchmarking progress.[141] CRSB is a member of the Global Roundtable for Sustainable Beef whose other members include Brazilian, Colombian, US and European Roundtables.[142]
•	**4-R Nutrient Stewardship** is an initiative of Fertilizer Canada promoting the use of the Right Source at the Right Rate, Right Time, and Right Place®.[143] A number of environmental concerns related to fertilizer use are evident across Canada, including excessive phosphorous loadings, nitrate levels in drinking water, soil conservation, salinity, and soil and air quality concerns. 4R Nutrient Stewardship research provides crop producers with science-based information and advice on how to use BMPs to reduce GHG emissions and address other environmental impacts when they apply fertilizers. This ultimately helps producers improve farm profitability by optimizing returns to fertilizer expenditures, increase productivity of farm labour by adopting new practices that prevent nutrient loss from cropping systems, increase efficiencies and reduce costs per unit of crop harvested, and improve recycling of crop nutrients from crop residues and livestock manures. More than 60 percent of farmers are familiar with the program and Fertilizer Canada aims to reach an adoption rate of 20 % of total crop area, which is over 93 million acres, in 2020. [144-145]
•	The **Natural Capital Coalition** is a unique global multi-stakeholder collaboration that brings together almost 250 leading global businesses, organizations and governments to develop a common vision of a world where business conserves and enhances natural capital.[146] It is the outcome of the growing recognition of the dependencies of business risks and/or opportunities on natural capital, and the growing need to conserve and enhance natural capital. "*We know that we are depleting natural resources faster than the earth can replenish them, and at an accelerating rate. We have grown financial*

[141] National Beef Sustainability Assessment and Strategy Summary Report. Accessed at: https://crsb.ca/assets/Uploads/About-Us/Our-Work/NBSA/290ae9c611/NBSA_and_Strategy_summary_report_web1.pdf.
[142] Global Roundtable for Sustainable Beef. Accessed at: https://grsbeef.org/.
[143] Fertilizer Institute, "4R Stewardship Program." Accessed at: https://fertilizercanada.ca/nutrient-stewardship/.
[144] Pulse Canada, "Fertilizer Use Survey." Accessed at: https://fertilizercanada.ca/resource/fertilizer-use-survey-building-database-fertilizer-management-practices/.
[145] Statistics Canada, "Census of Agriculture 2016." Accessed at: https://www.statcan.gc.ca/eng/ca2016.
[146] National Capital Coalition. Accessed at: https://naturalcapitalcoalition.org/.

capital in large part through the use, exploitation, and degradation of natural and social capital." The Coalition developed the Natural Capital Protocol for the inclusion of natural capital into business decision- making in a consistent and standardized fashion that would allow businesses to identify, measure, and value impacts and dependencies on natural capital. This first two guides developed in 2016 were for the food and beverage and apparel sectors, followed by other industries. [147]
• **Nature Conservancy of Canada (NCC)** is Canada's leading national, private land conservation organization with the aim of protecting and caring for our most ecologically significant lands and waters and the species they sustain.[148] Founded in 1962 the Nature Conservancy of Canada (NCC) has grown to become the largest land trust in Canada. To date NCC has helped conserve over 4 million acres of land and worked with over 1300 landowners. A science-based conservation planning process drives their work, partnering with individuals, governments, indigenous communities, corporations and others to achieve durable conservation solutions. NCC secures properties through donation, purchase, conservation agreement and the relinquishment of other legal interests, and manages them for the long term. Since 1962, NCC and its partners, including Environment and Climate Change Canada, through the Natural Areas Conservation Program, have helped conserve more than 1.1 million hectares (2.8 million acres) of ecologically significant land from coast to coast.[149]
• **Ducks Unlimited Canada (DUC)** is a non-profit charitable organization that was established in 1938, with the goal of conserving, restoring and managing wetlands and grasslands across Canada to benefit waterfowl, wildlife and people for generations to come[150]. Through a combination of government funding, donations and volunteers, who give of their time and efforts, DUC has been able to complete more than 11,890 projects and conserve, restore and influence more than 163.5 million acres of habitat.

[147] National Capital Protocol. Accessed at: https://naturalcapitalcoalition.org/natural-capital-protocol/.
[148] Nature Conservancy of Canada. Accessed at: http://www.natureconservancy.ca/en/what-we-do/conservation-program/?gclid=Cj0KCQjww8jcBRDZARIsAJGCSGvN6jxjAFR-_lRAAiTU21ZtI-5T7RCuv_CNgRVoJTyy2TUV9wj0ZPAaArZ3EALw_wcB.
[149] Natural Areas Conservation. Accessed at: http://www.natureconservancy.ca/en/what-we-do/conservation-program/.
[150] Ducks Unlimited Canada, accessed at: https://www.ducks.ca/about/

Annex C: Policies Promoting Environmental Performance in Other Countries

Other countries, like Canada, have introduced policies and initiatives to help mitigate the environmental impacts of agriculture and promote sustainable agricultural production, which includes the EU and the U.S.

The EU provides support to its farmers through its Common Agricultural Policy (CAP) with both direct payments to farmers and market interventions to stabilize farm income and to promote rural development.[151] Instruments for promoting environmental and climate include **cross-compliance**, which ties direct payments for farm income support to a set of basic standards of practice, ensuring good agricultural and environmental conditions of land with penalties for not adhering to these practices. **Subsidies** are also available for voluntarily applying certain practices that benefit the environment and climate under rural development programs.[152] For the past few years, CAP payments of about EU40 billion annually were committed to these programs.

In 2013, the EU introduced what is called "**greening**" of CAP to enhance environmental performance of the sector.[153] The greening payments, which commenced in 2016, were to reward the farmers for the environmental benefits from certain farming practices, specifically, 1) crop diversification- in an effort to promote soil quality, 2) maintenance of permanent grassland- to promote biodiversity and sequester carbon, and 3) maintaining land with specific characteristics or "ecological focus areas" to improve biodiversity.[154] The program attempted to reward farmers for the positive externalities they provide that otherwise would not be rewarded by the market.

In December 2017, the EU Court of Auditors published an evaluation of the "greening" program and concluded that it deficient at benefiting the environment and climate because it did not clearly define its targets for achieving EU soil, climate and biodiversity improvements due to lack of data, ineffective targeting (crop diversification vs. rotation), overly generous payments and high complexity. As a result, the program duplicated CAP's income support scheme, and only 5% of EU farmland saw changes in farming practices that would benefit the environment.[155]

[151] EU Court of Auditors, "Greening: A More Complex Income Support Scheme, Not Yet Environmentally Effective," Dec. 2017. Accessed at: http://publications.europa.eu/webpub/eca/special-reports/greening-21-2017/en/.
[152] Ibid, pg. 10.
[153] Ibid, pg. 8.
[154] Ibid, pg. 10.
[155] Ibid.

The U.S. has a longer history of agri-environmental programming than the EU and considers the conservation of critical natural capital a legitimate task of government.[156] The first **conservation programs** were introduced in the U.S. in the 1930s, focused on protecting the soil and reducing production of certain crops that were in excess supply. More recently, since the 1980s, other agri-environmental programs have been funded under the various U.S. Farm bills, to reduce water pollution from nutrient run-off of livestock facilities, such as the **Environmental Quality Incentives program** introduced in 2002, where new stricter regulations on nutrient management of large livestock operations with payments to implement new practices were introduced.[157] Other initiatives targeted the reduction of GHG and other chemical emissions from farming that lead to air pollution and climate change, and to enhance wildlife habitat for improved biodiversity. U.S. agri-environmental programs have been primarily focussed on reducing the negative externalities produced by agriculture. This compares with the EU, where agri-environmental policies developed since the 1980s under CAP have tended to focus more on increasing the positive externalities or "multifunctionality" of agriculture, such as landscape benefits and agri-tourism.[158]

Compared to the EU, the U.S. agri-environmental and conservation programs tend to be focussed on more easily measured targets, while the EU programs are targeted toward multiple, sometimes nebulous goals. Since the degree of targeting can determine how well a program meets its objectives, evidence suggests that the US environmental programs are more effective than the EU ones at achieving their goals.[159]

[156] K. Bayliss, S. Peplow, G. Rausser, L. Simon, "Agri-environmental policies in the EU and United States: A comparison, Ecological Economics," 2008, pg. 754.
[157] Ibid, pg. 755.
[158] Ibid.
[159] Ibid, pg. 757.