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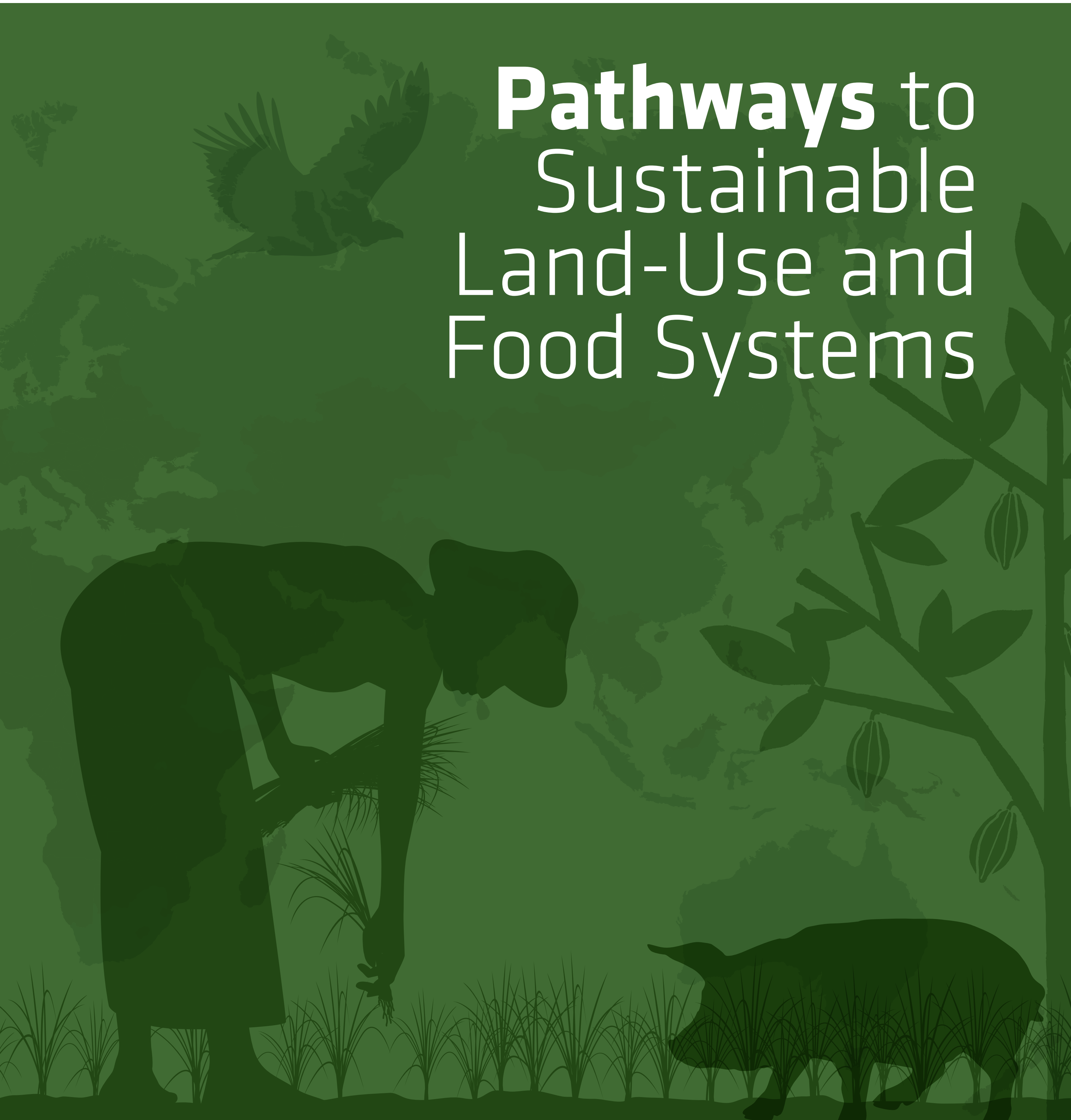
The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



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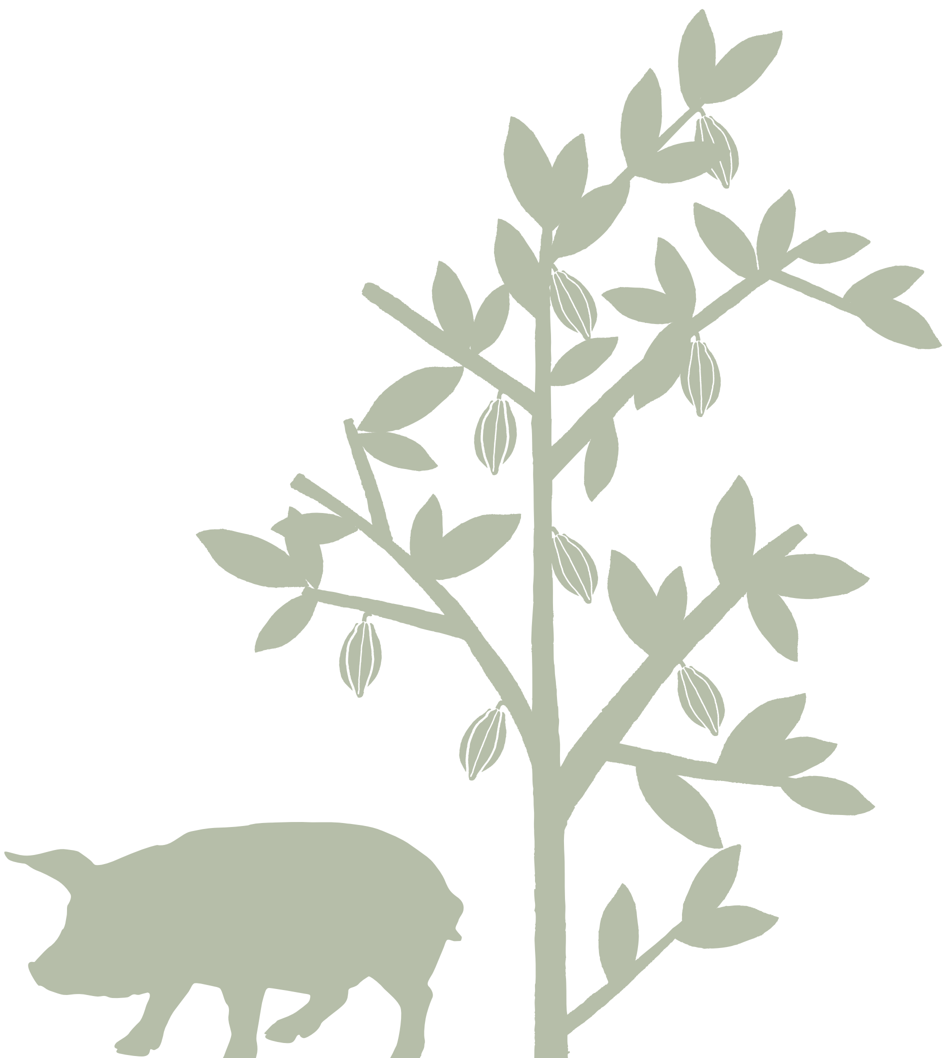
2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems in Canada by 2050



Canada

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This chapter of the 2020 Report of the FABLE Consortium *Pathways to Sustainable Land-Use and Food Systems* outlines how sustainable food and land-use systems can contribute to raising climate ambition, aligning climate mitigation and biodiversity protection policies, and achieving other sustainable development priorities in Canada. It presents three pathways for food and land-use systems for the period 2020-2050: Current Trends, Sustainable Medium Ambition, and Sustainable High Ambition (referred to as "Current Trends", "Sustainable", and "Sustainable+" in all figures throughout this chapter). These pathways examine the trade-offs between achieving the FABLE targets under limited land availability and constraints to balance supply and demand at national and global levels. We developed these pathways based on an extensive review of peer-reviewed literature and government policy documents and modeled them with the FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019). See Annex 1 for more details on the adaptation of the model to the national context.

Climate and Biodiversity Strategies and Current Commitments

Countries are expected to renew and revise their climate and biodiversity commitments ahead of the 26th session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 15th COP to the United Nations Convention on Biological Diversity (CBD). Agriculture, land use, and other dimensions of the FABLE analysis are key drivers of both greenhouse gas (GHG) emissions and biodiversity loss and offer critical adaptation opportunities. Similarly, nature-based solutions, such as reforestation and carbon sequestration, can meet up to a third of the global emission reduction needs for the Paris Agreement (Roe et al., 2019). Countries' biodiversity and climate strategies under the two Conventions should therefore develop integrated and coherent policies that cut across these domains, in particular through land-use planning which accounts for spatial heterogeneity.

Table 1 summarizes how Canada's Nationally Determined Contribution (NDC) and Long Term Low Emissions and Development Strategy (LT-LEDS) relate to the FABLE domains. According to the LT-LEDS, Canada has committed to reducing its GHG emissions by 80% by 2050 compared to 2005. This includes emission reduction efforts from agriculture, forestry, and other land use (AFOLU). Envisaged mitigation measures from agriculture and land-use change include protecting and enhancing carbon sinks including forests, wetlands and agricultural lands; large-scale afforestation; increased use of long-lived harvested wood products; and increased utilization of waste wood biomass. Under its current commitments to the UNFCCC, Canada does not mention biodiversity conservation.

Table 1 | Summary of the mitigation target, sectoral coverage, and references to biodiversity and spatially-explicit planning in current NDC and LT-LEDS

	Total GHG Mitigation					Mitigation Measures Related to AFOLU (Y/N)	Mention of Biodiversity (Y/N)	Inclusion of Actionable Maps for Land-Use Planning[1] (Y/N)	Links to Other FABLE Targets
	Baseline		Mitigation target		Sectors included				
	Year	GHG emissions (Mt CO_2e/yr)	Year	Target					
NDC (2017)	2005	747	2030	30% reduction	Energy, industrial processes, agriculture, land-use change and forestry, and waste	N	N	N	Deforestation
LT-LEDS (2016)	2005	748	2030	80% reduction	Energy, Industrial processes and product use, agriculture, and wastes	Y	N	N	Food security, water, and deforestation

Note. "Total GHG Mitigation" and "Mitigation Measures Related to AFOLU" columns are adapted from Institute for Global Environmental Strategies (IGES) NDC Database (Hattori, 2019)
Source: Canada (2017)

1 We follow the United Nations Development Programme definition, "maps that provide information that allowed planners to take action" (Cadena et al., 2019).

Table 2 provides an overview of the biodiversity targets included in the National Biodiversity Strategies and Action Plan (NBSAP), as listed on the CBD website (CBD, 2020). Canada's NBSAP combines its 2020 Biodiversity Goals and Targets and the 2006 Biodiversity Outcomes Framework, which are related to at least one of the FABLE Targets. In comparison with the FABLE Targets, the NBSAP Targets are somewhat vague and unambitious.

Table 2 | Overview of the latest NBSAP targets in relation to FABLE targets

NBSAP Target	FABLE Target
(6) **By 2020, continued progress is made on the sustainable management of Canada's forests.**	**DEFORESTATION:** Zero net deforestation from 2030 onwards
(A) **By 2020, Canada's lands [...] are planned and managed using an ecosystem approach to support biodiversity conservation outcomes at local, regional, and national scales.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(1) **By 2020, at least 17 percent of terrestrial areas and inland water [...] are conserved through networks of protected areas and other effective area-based conservation measures.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(3) **By 2020, Canada's wetlands are conserved or enhanced to sustain their ecosystem services through retention, restoration, and management activities.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(7) **By 2020, agricultural working landscapes provide a stable or improved level of biodiversity and habitat capacity.**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(15) **By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced through conservation and restoration actions, including restoration of at least 15% of degraded ecosystems, prioritizing the most degraded biomes, hydrographic regions and ecoregions, thereby contributing to climate change mitigation and adaptation and to combatting desertification.**	**GHG EMISSIONS:** Zero or negative global GHG emissions from LULUCF by 2050

Brief Description of National Pathways

Among possible futures, we present three alternative pathways for reaching sustainable objectives, in line with the FABLE Targets, for food and land-use systems in Canada.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by high population growth (from 38 million in 2020 to 49 million in 2050), no constraints in agricultural expansion, no afforestation target, no change in the extent of protected areas, low productivity increases in the agricultural sector, an evolution towards high-fat diets, and high economic growth (see Annex 2). This corresponds to a future based on current policy and historical trends that would also see considerable growth in GDP and exports in the coming decades, according to OECD (2020a) and FAO (2019) database projections. Moreover, as with all FABLE country teams, we embed this Current Trends Pathway in a global GHG concentration trajectory that would lead to a radiative forcing level of 6 W/m^2 (RCP 6.0), or a global mean warming increase likely between 2°C and 3°C above pre-industrial temperatures, by 2100. Our model includes the corresponding climate change impacts on crop yields by 2050 for rapeseed, barley, wheat, and soybeans, which are the main agricultural products exported by Canada (see Annex 2).

Our Sustainable Medium Ambition Pathway represents a future in which significant efforts are made to adopt sustainable policies and practices and corresponds to an intermediate boundary of feasible action. Compared to the Current Trends Pathway, we assume that this future would lead to higher afforestation rates, expansion of protected areas, improved crop and livestock productivities, expanded imports and exports, and greater biofuel consumption. It is also characterized by lower population and GDP growth rates, a lower deforestation rate, reduced calorie consumption, and a declining share of wasted food (see Annex 2). This corresponds to a future based on the adoption and implementation of new ambitious policies on trade, immigration, and climate change that would also see considerable progress concerning biodiversity protection (more and larger protected areas), first generation biofuel consumption, sustainable forest management, and agricultural performance (Bohnert et al., 2015; Mukhopadhyay et al., 2020; Prestele et al., 2016; Wulder et al., 2018). With the other FABLE country teams, we embed this Sustainable Medium Ambition Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m^2 by 2100 (RCP 2.6), in line with limiting warming to 2°C. At this level of warming this pathway assumes a positive impact of climate change on crop and pastures productivities given resulting increases in the growing season and suitable agricultural area (Assefa et al., 2018; Jing et al., 2017; Li et al., 2013; Lychuk et al., 2017; Qian et al., 2016; Ray et al., 2013; Thomas & Graf, 2014).

Our Sustainable High Ambition Pathway represents a future in which even more significant efforts are made to adopt sustainable policies and practices and corresponds to the highest boundary of feasible action. Compared to the Sustainable Medium Ambition Pathway, we assume that this future would lead to even higher afforestation rates, expansion of protected areas, improvements to the productivity of key crops, and increased exports. This is coupled with lower GDP growth, reduced imports, and declining use of first-generation biofuel consumption (see Annex 2). This corresponds to a future based on the adoption and implementation of very ambitious policies on biodiversity protection (Andrew et al., 2012; Schulte, 2017) and climate change mitigation programs, like the zero-emission vehicles (ZEVs) target that includes subsidies and other support programs to increase the use of electric vehicles (Natural Resources Canada, 2020). As in the Sustainable Medium Ambition Pathway, we embed this Sustainable High Ambition Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

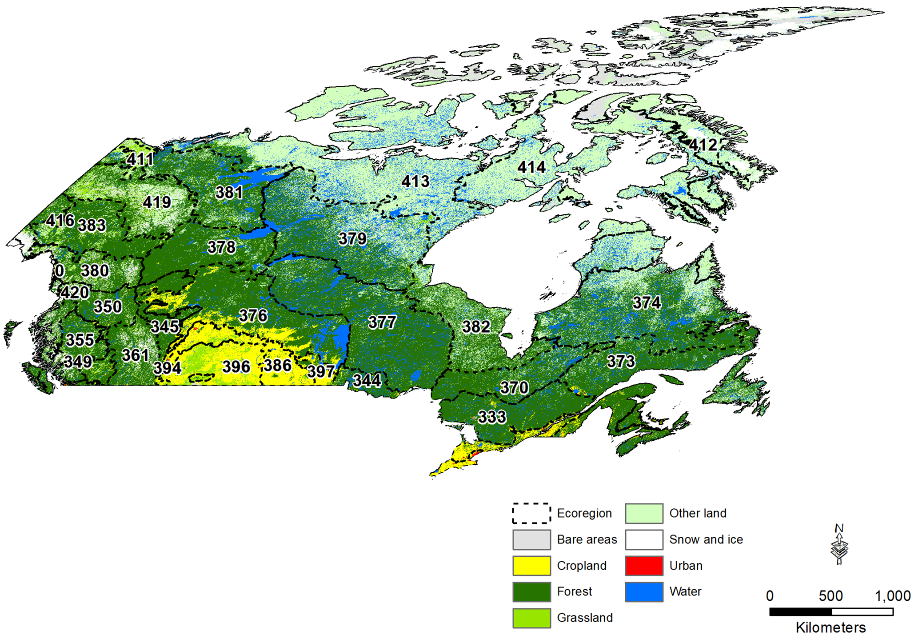
Land and Biodiversity

Current State

In 2010, Canada was covered by 5.8% cropland, 1.6% grassland, 38.1% forest, 0.1% urban and 54.3% other natural land. Most of the agricultural area is located in the provinces of Alberta and Saskatchewan, while forest and other natural land can be mostly found in British Columbia, Ontario, Manitoba, Quebec, and the northern territories (Map 1). The main issues for biodiversity conservation are related to energy production and mining (tar sands production in Alberta), increase in fire frequency and intensity (wildfires in the western region), and diseases that increase natural mortality and produce ecological imbalances.

We estimate that land where natural processes predominate[2] accounted for 80% of Canada's terrestrial land area in 2010 (Map 2). The 411-Brooks-British Range tundra ecoregion holds the greatest share of land where natural processes predominate, followed by the 419-Ogilvie-MacKenzie alpine tundra ecoregion and the 380-Northern Cordillera forests ecoregion (Annex 4). Across the country, while 107Mha of land is under formal protection, falling short of the 30% zero-draft CBD post-2020 target, only 17% of land where natural processes predominate is formally protected. This indicates that the 405-Alaska-St. Elias Range tundra, the 396-Northern Shortgrass prairie, and the 365-Queen Charlotte Islands conifer forests ecoregions will remain important for biodiversity into the future as a significant share of their surface is protected. By contrast, the 383-Watson Highlands taiga, the 345-Alberta-British Columbia foothills forests, and the 416-Interior Yukon-Alaska alpine tundra ecoregions may be at risk without action to better protect them.

Map 1 | Land cover by aggregated land cover types in 2010 and ecoregions



Notes. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 3.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)

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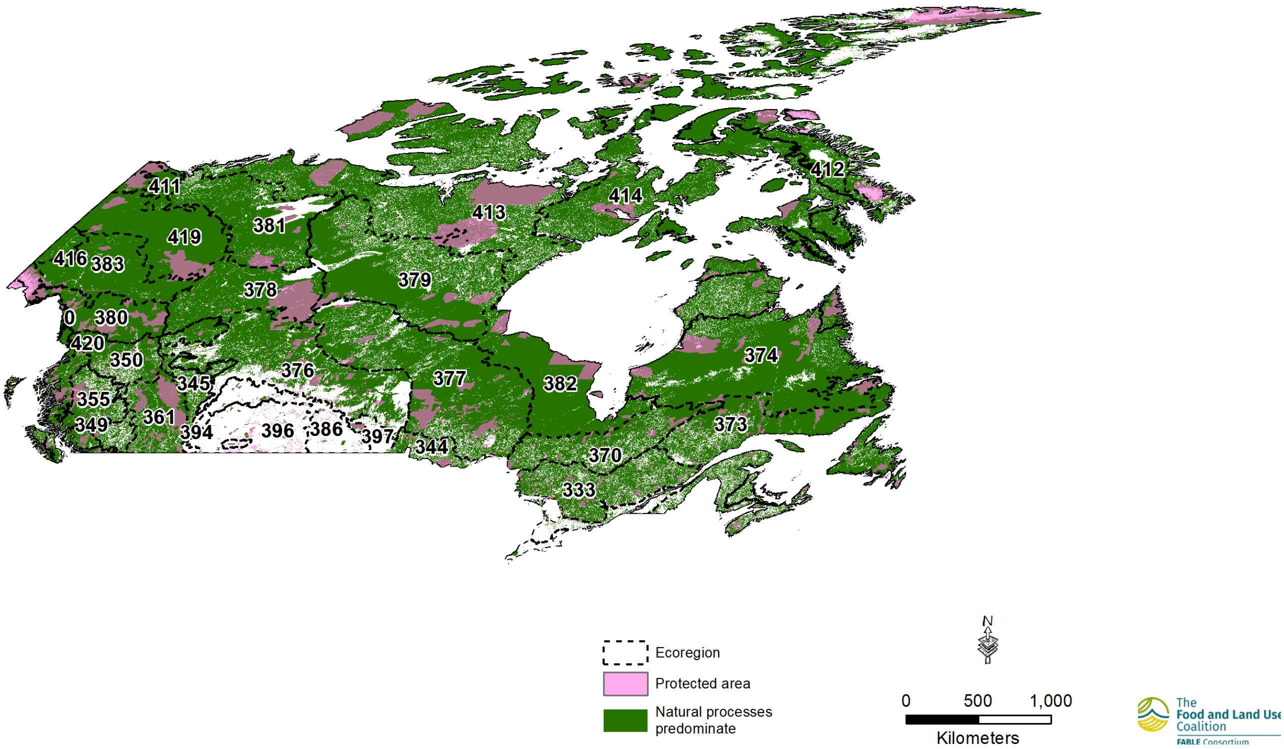
2 We follow Jacobson, Riggio, Tait, and Baillie (2019) definition: "Landscapes that currently have low human density and impacts and are not primarily managed for human needs. These are areas where natural processes predominate, but are not necessarily places with intact natural vegetation, ecosystem processes or faunal assemblages".

Canada

Approximately 20.8% of Canada's cropland was in landscapes with at least 10% natural vegetation in 2010. These relatively biodiversity-friendly croplands are most widespread in 386-Canadian Aspen forests and parklands, followed by 396-Northern Shortgrass prairie and 376-Mid-Canada Boreal Plains forests. The regional differences in extent of biodiversity-friendly cropland can be explained by regional production intensity.

Map 2 | Land where natural processes predominated in 2010, protected areas and ecoregions



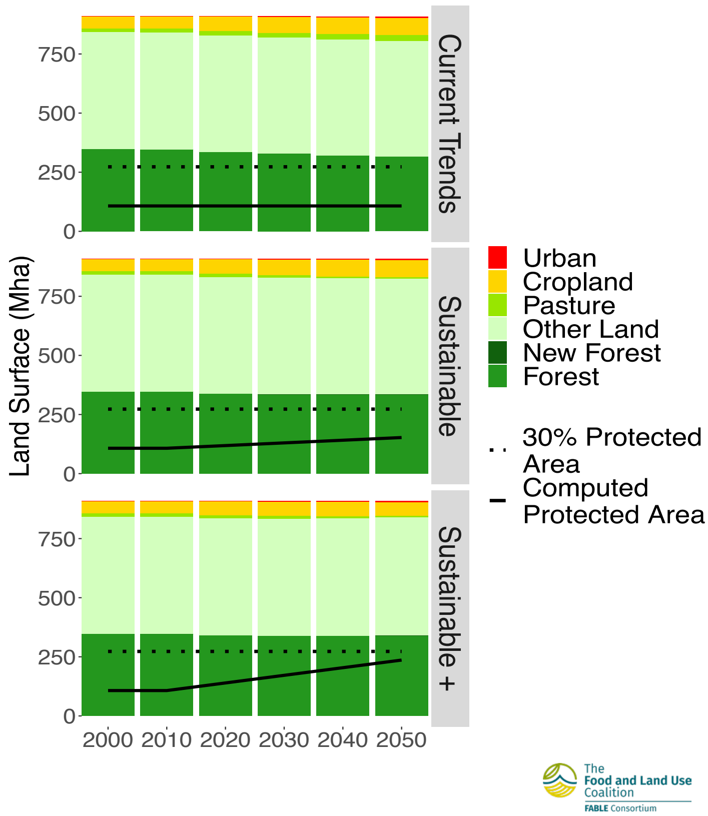
Note. Protected areas are set at 50% transparency, so on this map dark purple indicates where areas under protection and where natural processes predominate overlap.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International (2019), intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

Pathways and Results

Projected land use in the Current Trends Pathway is based on several assumptions, including no constraints on land conversion beyond protected areas, no planned afforestation or reforestation, and protected areas remain at 107 Mha, representing 11% of total land cover (see Annex 2).

By 2030, we estimate that the main changes in land cover in the Current Trends Pathway will result from an increase in cropland and a decrease in forest area. This trend remains stable over the period 2030-2050: cropland area further increases, and forest area decreases (Figure 1). The expansion of the planted area for rapeseed, wheat and barley explains 72% of total cropland expansion between 2010 and 2030. For rapeseed, 57% of expansion is explained by an increase in exports, mainly to China, and 43% an increase in domestic consumption (processed food). For wheat, 36% of expansion is due to an increase in exports and 64% an increase in domestic consumption (feeding animals, food, and biofuels). Finally, for barley, 98% results from an increase in domestic consumption for feeding animals. Pasture expansion is mainly driven by the increase in internal food consumption of beef, milk, and derivatives, while livestock productivity per head increases and ruminant density per hectare of pasture remains constant over the period 2020-2030. Between 2030-2050, deforestation is explained by cropland and pastures expansion. This results in a reduction in land where natural processes predominate by 5% by 2030 and by 9% by 2050 compared to 2010, respectively.
In the Sustainable Medium Ambition and

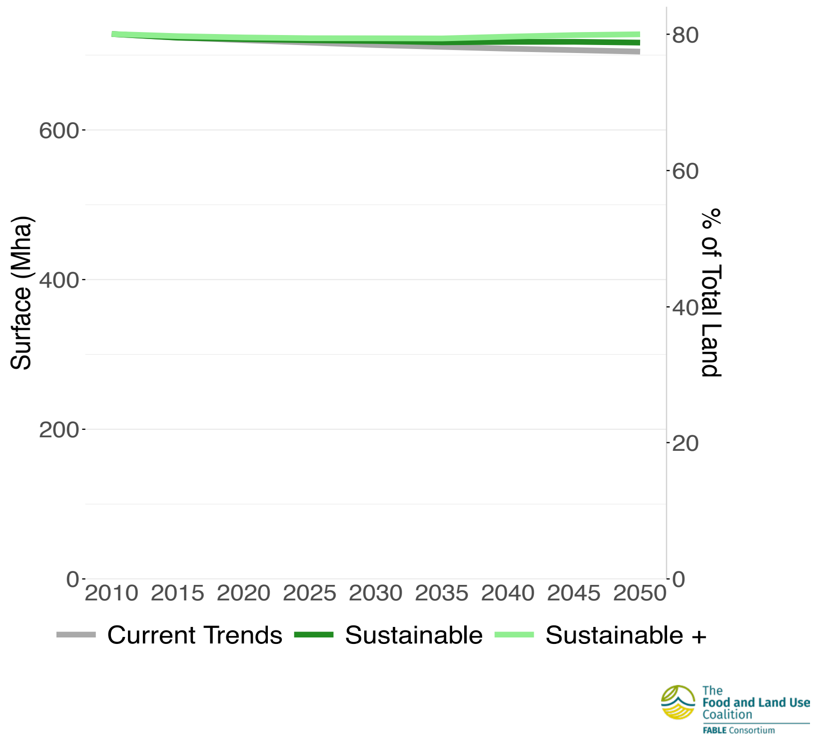
Figure 1 | Evolution of area by land cover type and protected areas under each pathway



Source. Authors' computation based on ESA (2010), for the area by land cover type for 2000, and the World Database on Protected Areas (UNEP-WCMC & IUCN, 2020) for protected areas for years 2000, 2005 and 2010.

Sustainable High Ambition Pathways, assumptions on agricultural land expansion, reforestation, and protected areas have been changed to reflect a higher interest in biodiversity conservation and climate change mitigation (Prestele et al., 2016; Wulder et al., 2018). For the Sustainable Medium Ambition Pathway, the main assumptions include the prevention of deforestation by 2030, 1 Mha afforested by 2050, and protected areas increase from 11% of total land in 2010 to 17% in 2030 (see Annex 2), while for the Sustainable High Ambition Pathway afforested area increases by 2Mha and protected areas to 28%.

Figure 2 | Evolution of the area where natural processes predominate



Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in Canada in the Sustainable Medium Ambition and Sustainable High Ambition Pathways: (i) a lower deforestation rate, (ii) a small increase in natural land, (iii) the stabilization or even a smaller area of agricultural land, and (iv) a higher afforested land. In addition to the changes in assumptions regarding land-use planning, these changes compared to the Current Trends Pathway are explained by the internal demand for food due to changing diets, a lower population growth rate, between the Current Trends and the Sustainable Pathways, and higher crop productivities (increased productivity leads to reductions in the land required to produce the same volume). This leads to an increase in the area where natural processes predominate: the area stops declining by 2025 and increases by 1% between 2025 and 2050 (Figure 2).

GHG emissions from AFOLU

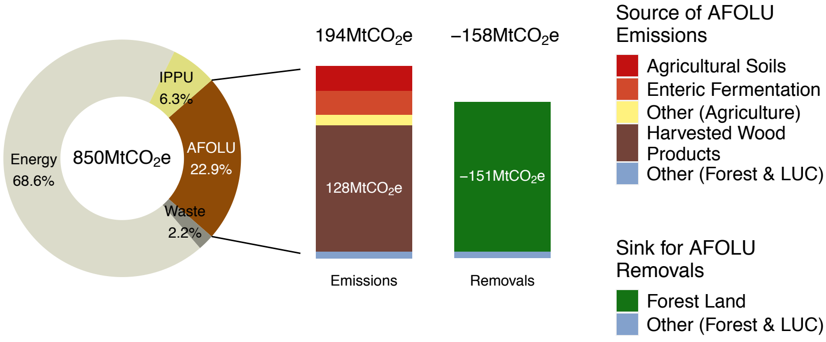
Current State

Direct GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) accounted for 23% of total emissions in 2010 (Figure 3). Harvested wood products is the principle source of AFOLU emissions, followed by enteric fermentation, and agricultural soils. The relatively large emissions from harvested wood products reflects the state of the forestry industry in Canada. The Canadian forest industry contributes over $20 billion to Canada's GDP, employs over 200,000 workers and harvests roughly 150 million cubic meters of roundwood per year (Natural Resources Canada, 2018). Over 95% of the enteric fermentation in Canada comes from raising cattle, primarily for beef but also for dairy. There are slightly over 10 million head of cattle in Canada (Environment and Climate Change Canada, 2020).

Pathways and Results

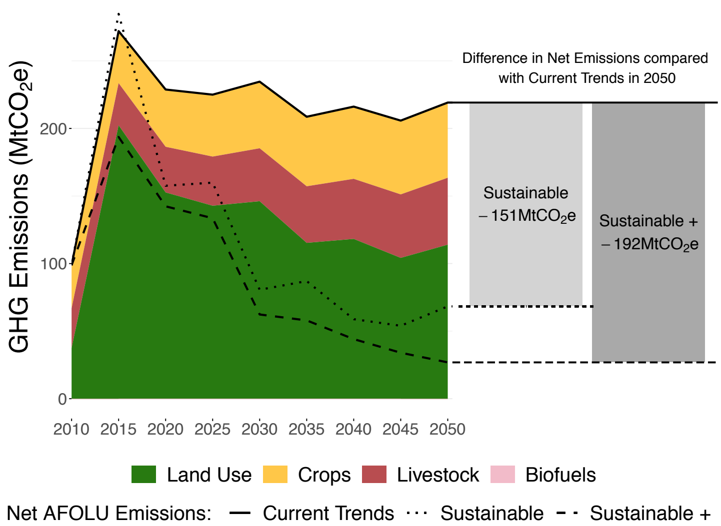
Under the Current Trends Pathway, annual GHG emissions from AFOLU increase to 235 Mt CO_2e/yr in 2030, before reaching 219 Mt CO_2e/yr in 2050 (Figure 4). The abrupt increase in GHG emissions between 2010 and 2015 is the result of an overestimated projection of the increase in key crop production levels, particularly

Figure 3 | Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total AFOLU emissions and removals by source in 2010



Note. IPPU = Industrial Processes and Product Use
Source. Adapted from GHG National Inventory (UNFCCC, 2020)

Figure 4 | Projected AFOLU emissions and removals between 2010 and 2050 by main sources and sinks for the Current Trends Pathway

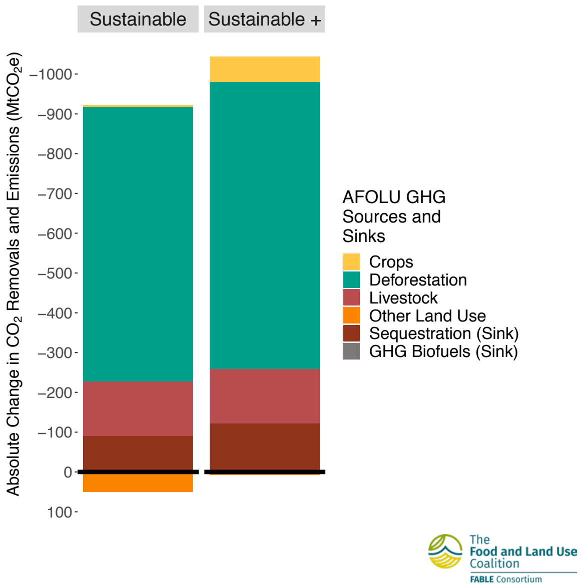


rapeseed and soybeans. This overestimation results from an exponential increase in the production levels of these crops due to a higher Chinese demand between 2005 and 2015. Values decrease after 2015 to reach more realistic values toward 2020 and beyond. In 2050, methane produced by livestock is the single largest source of emissions (35Mt CO_2e per year) while forest regeneration acts as a sink (-1 Mt CO_2e per year). Over the period 2020-2050, the strongest relative increase in GHG emissions is computed for livestock (47%) while a reduction is computed for deforestation (25%).

In comparison, the Sustainable Medium Ambition Pathway leads to a reduction of AFOLU GHG emissions by 69% and the Sustainable High Ambition Pathway to a reduction by 88% by 2050 compared to the Current Trends Pathway (Figure 4). The potential emissions reductions under the Sustainable Medium Ambition Pathway is dominated by a reduction in GHG emissions from deforestation and livestock production (Figure 5). The most important drivers of this reduction are a lower population growth rate by 2050, a healthier diet and limiting agricultural expansion such that it does not affect forests beyond 2030. Under the Sustainable High Ambition Pathway, GHG emissions from agriculture (crops), and land-use change are further reduced thanks to a higher afforestation rate and a lower consumption of first-generation biofuels.

Compared to Canada's commitments under the UNFCCC (Table 1), our results show that AFOLU could contribute to as much as 69% of its total GHG emissions reduction objective by 2030. Such reductions could be achieved through the following policy measures: banning deforestation beyond 2030; promoting afforestation for carbon sequestration and biodiversity conservation in the context of initiatives like the Bonn Challenge; increasing protected areas (Aichi Biodiversity Targets and beyond); sowing higher productivity crops and improving livestock genetics and pasture productivity; shifting Canadian diets toward the recommendations of the EAT-Lancet Commission; and increasing the use of zero-emission vehicles instead of those based on crop-based biofuels. These measures could be particularly important when considering options for NDC enhancement.

Figure 5 | Cumulated GHG emissions reduction computed over 2020-2050 by AFOLU GHG emissions and sequestration source compared to the Current Trends Pathway



Food Security

Current State

The "Triple Burden" of Malnutrition

Undernutrition

2.5% of the population undernourished in 2017. This share has remained relatively constant since 2000 (World Bank, 2017).

Data on the proportion of children under 5 who exhibit stunting and wasting due to malnutrition was not available for Canada. It may not appear chronically within the general population.

Micronutrient Deficiency

4% of women and 2% of children suffer from anemia in 2011, which can lead to maternal death (Cooper et al., 2012).

In 2012 it was estimated that 35% of the population consumed levels of vitamin A below the estimated average requirements- a trend equal amongst men and women (Health Canada, 2012), which can notably lead to blindness (Martini et al., 2018) and child mortality, and 22% of the population is deficient in iodine, which can lead to developmental abnormalities (Statistics Canada, 2012).

Overweight/ Obesity

26.9% of the population, 24.4% of adults and 10.6% of children were obese in 2017 (Statistics Canada, 2017). While the share of childhood obesity has dropped since 2009, levels in the adult and overall population have risen.

33.5% of the population, 31.1% of adults, and 18.3% of children, were overweight in 2017 (Statistics Canada, 2017). Records indicate that the percentage of overweight children has risen over the past decade, while overall levels have fallen. (Rao et al., 2016; Statistics Canada, 2017)

Disease Burden due to Dietary Risks

10% of deaths are attributable to dietary risks, or nearly 30,000 individuals (Kaczorowski et al., 2016).

In 2015, 9.3% of the population suffered from diabetes (Statistics Canada, 2018) and 8.5% from cardiovascular diseases, which can be attributable to dietary risks (Public Health Canada, 2017).

Table 3 | Daily average fats, proteins and kilocalories intake under the Current Trends, Sustainable Medium Ambition, and Sustainable High Ambition Pathways in 2030 and 2050

	2010	2030			2050		
	Historical Diet (FAO)	Current Trends	Sustainable Medium Ambition	Sustainable High Ambition	Current Trends	Sustainable Medium Ambition	Sustainable High Ambition
Kilocalories (MDER)	2,710 (2,104)	2,994 (2,092)	2,569 (2,092)	2,569 (2,092)	3,276 (2,086)	2,304 (2,086)	2,304 (2,086)
Fats (g) (recommended range)	125 (60-90)	141 (66-100)	118 (57-86)	118 (57-86)	157 (73-109)	104 (51-77)	104 (51-77)
Proteins (g) (recommended range)	85 (68-237)	99 (75-262)	84 (64-225)	84 (64-225)	112 (82-287)	81 (58-202)	81 (58-202)

Notes. Minimum Dietary Energy Requirement (MDER) is computed as a weighted average of energy requirement per sex, age class, and activity level (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) and the population projections by sex and age class (UN DESA, 2017) following the FAO methodology (Wanner et al., 2014). For fats, the dietary reference intake is 20% to 30% of kilocalories consumption. For proteins, the dietary reference intake is 10% to 35% of kilocalories consumption. The recommended range in grams has been computed using 9 kcal/g of fats and 4kcal/g of proteins.

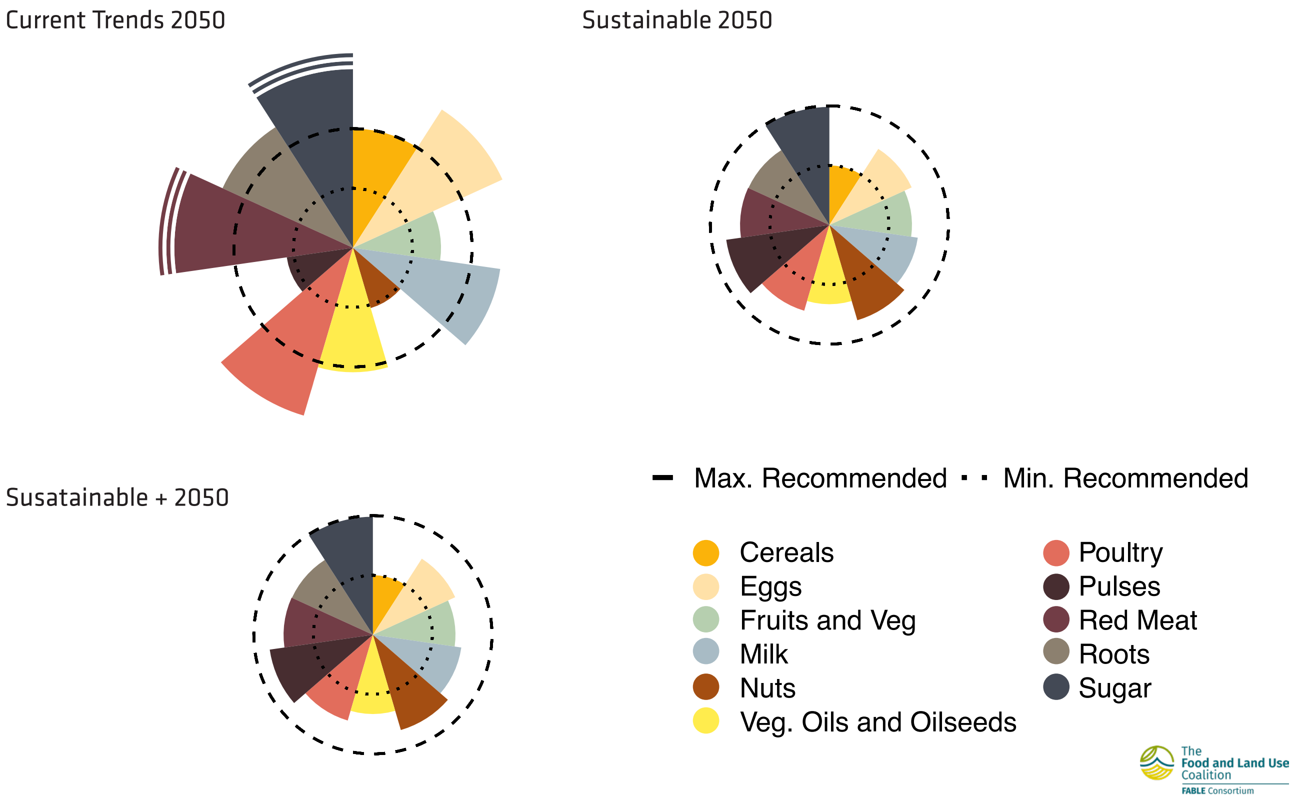
Pathways and Results

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 43% higher in 2030 and 57% higher in 2050 (Table 3). The current average intake is mostly satisfied by red meat, poultry, milk, eggs, roots and sugar, and animal products represent 21% of the total calorie intake. We assume that the consumption of animal products and in particular milk, will increase by 57% between 2020 and 2050. The consumption of red meat, poultry, and cereals will also increase while pulses, roots, and nuts consumption will decrease. Compared to the EAT-Lancet recommendations (Willett et al., 2019), red meat, poultry, eggs, sugar, roots, and milk are over-consumed while pulses and nuts are under-consumed in 2050 (Figure 6). Moreover, fat intake per capita exceeds the dietary reference intake (DRI) in 2030 and 2050, while protein intake remains in the recommended range. This can be explained by high consumption of red meat, milk, pork, and poultry (Table 3).

Under the Sustainable Medium Ambition Pathway, we assume that diets will transition towards a more balanced diet, with a higher consumption of pulses and vegetables in general, as recommended by the EAT-Lancet Commission. Similar assumptions are made under the Sustainable High Ambition Pathway. The ratio of the computed average intake over the MDER decreases to 86% in 2030 and 70% in 2050 under the two sustainable pathways. Compared to the EAT-Lancet recommendations, only the consumption of animal fat remains outside of the recommended range with the consumption of pulses and nuts being now within the recommended range (Figure 6). Moreover, the fat intake per capita still exceed the dietary reference intake (DRI) in 2030, showing some improvement compared to the Current Trends Pathway.

A significant change in diet is possible and would improve the health of the population and lead to more sustainable land and food systems (Willett et al., 2019). This is not only about energetic content; it is also about food quality and environmental impacts. A diet based on nuts, pulses, a higher consumption of fruits and vegetables, and a lower consumption of ultra-processed food and meat would make it possible to reduce GHG emissions and improve health outcomes. A healthier lifestyle will be particularly important to promote this shift in diets.

Figure 6 | Comparison of the computed daily average kilocalories intake per capita per food category across pathways in 2050 with the EAT-Lancet recommendations



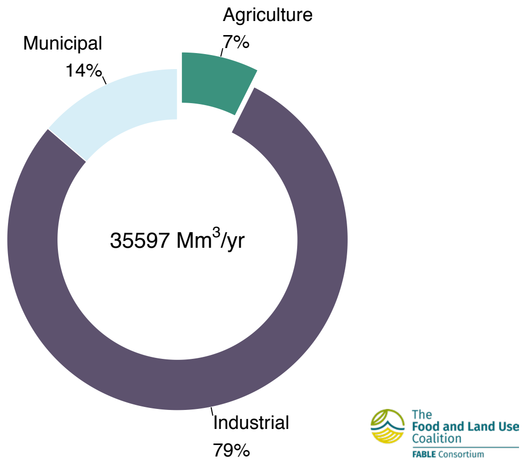
Notes. These figures are computed using the relative distances to the minimum and maximum recommended levels (i.e. the rings), therefore, the different kilocalorie consumption levels correspond to each circle depending on the food group. The EAT-Lancet Commission does not provide minimum and maximum recommended values for cereals: when the kcal intake is smaller than the average recommendation it is displayed on the minimum ring and if it is higher it is displayed on the maximum ring. The discontinuous lines that appear at the outer edge of sugar and red meat indicate that the average kilocalorie consumption of these food categories is significantly higher than the maximum recommended.

Water

Current State

Canada is characterized by an extremely cold climate with 537mm average annual precipitation that mostly occurs over the period November – March. The agricultural sector represented 7.4% of total water withdrawals in the period 2013-2017 (Figure 7; FAO, 2020). Moreover, in 2006, 2.4% of agricultural land was equipped for irrigation, representing 69% of estimated-irrigation potential (FAO, 2016). The three most important irrigated crops, cereals, fodder, and vegetables, account for 60%, 29%, and 5% of total harvested irrigated area. Canada exported 49% of cereals, 0% of fodder, and 19% of fresh vegetables in 2010 (FAO, 2019).

Figure 7 | Water withdrawals by sector in period 2015-2017

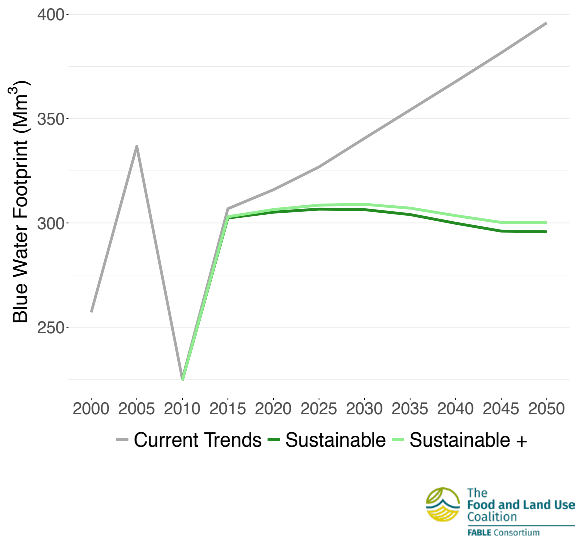


Notes. Agriculture and industrial data from 2015, municipal data from 2017.
Source. Adapted from AQUASTAT Database (FAO, 2017)

Pathways and Results

Under the Current Trends Pathway, annual blue water use increases between 2000-2015 (257 and 307 Mm^3/yr), before reaching 341 Mm^3/yr and 396 Mm^3/yr in 2030 and 2050, respectively (Figure 8), with barley, oilseeds, and oats accounting for 50%, 41%, and 8% of computed blue water use for agriculture by 2050[3]. In contrast, under the Sustainable Medium Ambition Pathway, blue water footprint in agriculture reaches 257 Mm^3/yr in 2030 and 143 Mm^3/yr in 2050, respectively, a trend that remains similar under the Sustainable High Ambition Pathway. This is explained by a change in the production level of cereals, and fodder due to a decline in internal feed demand.

Figure 8 | Evolution of blue water footprint in the Current Trends, Sustainable Medium Ambition and Sustainable High Ambition Pathways



3 We compute the blue water footprint as the average blue fraction per tonne of product times the total production of this product. The blue water fraction per tonne comes from Mekonnen and Hoekstra (2010a, 2010b, 2011). In this study, it can only change over time because of climate change. Constraints on water availability are not taken into account.

Resilience of the Food and Land-Use System

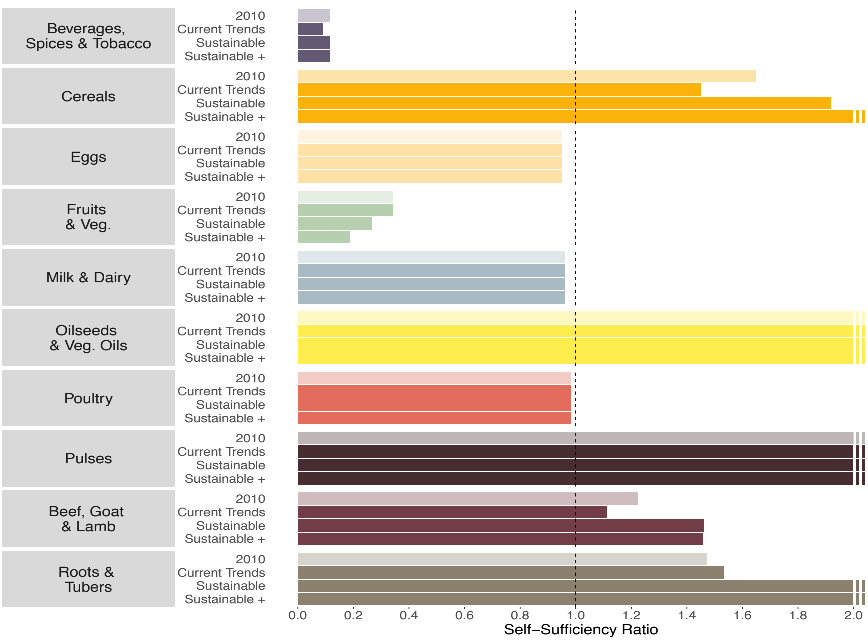
The COVID-19 crisis exposes the fragility of food and land-use systems by bringing to the fore vulnerabilities in international supply chains and national production systems. Here we examine two indicators to gauge Canada's resilience to agricultural-trade and supply disruptions across pathways: the rate of self-sufficiency and diversity of production and trade. Together they highlight the gaps between national production and demand and the degree to which we rely on a narrow range of goods for our crop production system and trade.

Self-Sufficiency

Canada is a large country in terms of territory but has a small population, which implies a positive supply to demand relationship between natural resources (fisheries, agricultural lands, forests, etc.) and people. Canada can be self-sufficient in cereals, fish, red meat, vegetables, and other food groups, as well as timber, energy, water and other goods and services. It should be noted that while production can exceed internal demand, for many products there is a two-way trade such that Canada both exports and imports within the same category of goods.

Under the Current Trends Pathway, we project that Canada would be self-sufficient in cereals, oilseeds and vegetable oils, poultry meat, pulses, read meat (beef, goat and lamb), and roots and tubers in 2050, with self-sufficiency by product group increasing for the majority of products from 2010 – 2050 (Figure 9). The product groups where the country depends the most on imports to satisfy internal consumption are beverages, spices and tobacco, fruits, and vegetables and this dependency will remain stable until 2050. Under the Sustainable Medium Ambition and the Sustainable High Ambition Pathways, Canada remains self-sufficient in the same eight product groups, but with higher self-sufficiency levels by 2050. This is explained by changes in the volume of imports and exports, productivity, and changes in diets.

Figure 9 | Self-sufficiency per product group in 2010 and 2050



Note. In this figure, self-sufficiency is expressed as the ratio of total internal production over total internal demand. A country is self-sufficient in a product when the ratio is equal to 1, a net exporter when higher than 1, and a net importer when lower than 1. The discontinuous lines on the right side of this figure, as appear for cereals and oilseeds and vegetable oils, indicate a high level of self-sufficiency in these categories.

Diversity

The Herfindahl-Hirschman Index (HHI) measures the degree of market competition using the number of firms and the market shares of each firm in a given market. We apply this index to measure the diversity/concentration of:

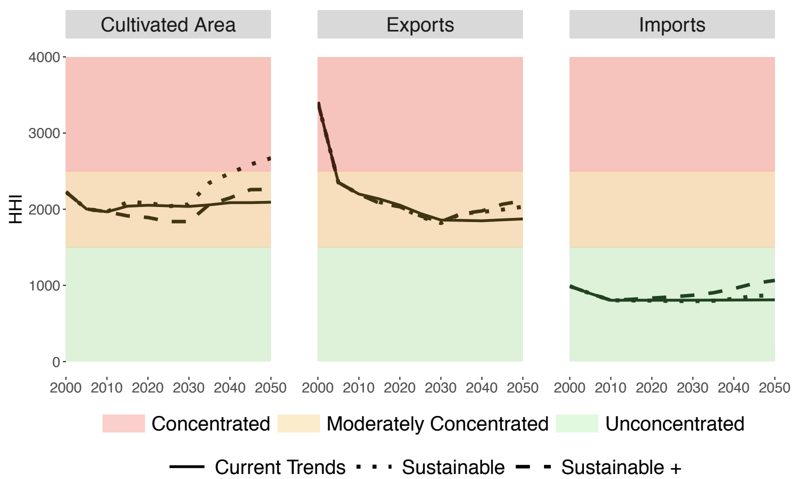
- **Cultivated area:** where concentration refers to cultivated area that is dominated by a few crops covering large shares of the total cultivated area, and diversity refers to cultivated area that is characterized by many crops with equivalent shares of the total cultivated area.
- **Exports and imports:** where concentration refers to a situation in which a few commodities represent a large share of total exported and imported quantities, and diversity refers to a situation in which many commodities account for significant shares of total exported and imported quantities.

We use the same thresholds as defined by the U.S. Department of Justice and Federal Trade Commission (2010, section 5.3): diverse under 1,500, moderate concentration between 1,500 and 2,500, and high concentration above 2,500.

Wheat and rapeseed were, by far, the main crop sown in 2010, follow by barley, soybeans, lentils, corn (for feed) and oats. Among these, rapeseed, wheat, barley, and soybeans are the main crops exported by Canada. According to the HHI, the planted crop area is moderately concentrated in 2010 as are exports (Figure 10).

Under the Current Trends Pathway, we project medium concentration of crop exports and planted area, and low concentration of imports in 2050, trends which stabilize over the period 2010 - 2050. This indicates moderate levels of diversity across the national production system and exports. Under the Sustainable Medium Ambition Pathway, we project a similar scenario, although a higher concentration of the planted area is possible, which is explained by a higher international demand of some specific crops from China and other important markets. Finally, under the Sustainable High Ambition Pathway, there is a medium and low concentration in exports and imports in 2050, respectively, indicate levels of diversity across the national production system that are similar to the Current Trends Pathway (Figure 10).

Figure 10 | Evolution of the diversification of the cropland area, crop imports, and crop exports using the Herfindahl-Hirschman Index (HHI)



Discussion and Recommendations

This document provides relevant data about the potential impact that different policies could have for increasing Canada's contribution to climate change mitigation, biodiversity conservation and solving other global challenges as laid out in the Sustainable Development Goals and other international initiatives.

By comparing three different pathways (Current Trends, Sustainable Medium Ambition, and Sustainable High Ambition), we assessed the effect that changes on population, GDP, agricultural production, international trade, and diet and life-styles would have on Canada´s greenhouse gas emissions, biodiversity, water consumption, and resilience of the food and land systems.

The population scenarios vary by about 10 million people by 2050 (50 million under the Current Trends compared to 40 million for the Sustainable Pathways). Population growth along with the levels and types of consumption (e.g. diets) are key factors because they determine the size of the economy, and the resulting pressure on food and land systems, energy consumption, and natural resources depletion.

Diet and lifestyles are key drivers of land-use outcomes, as clearly shown in our modeling results. A high consumption of red meat, pork, and ultra-processed food significantly increases Canada's GHG emissions and is related to a higher share of wasted food (throughout the distribution supply chain), as well as an increased prevalence of health issues. We recommend the inclusion of diets and life-style in climatic policy, as proposed by the EAT-Lancet Commission (Willett et al., 2019), the promotion of physical activity and the consumption of vegetables, fruits, and high-protein content food, such as fish and pulses, which are abundant and locally produced in Canada.

Moreover, international trade is another key driver related to the use of ecosystems. The Canadian internal market for agricultural products is small compared to the country's productive capacity and much of Canada's production is oriented towards the international market, especially the US and China. Canadian agricultural production is moderately concentrated in a group of crops: rapeseed, wheat, barley, soybeans, and lentils. All of this implies a high level of economic dependency and vulnerability, which has been evident in the past cases of political tension between Canada and its trade partners. Diversifying agricultural production and the number of trade partners would allow for potentially greater resilience and independence in Canada's policy development around climate change, land use and environmental and social sustainability.

Our results also show that forests have a key role in reducing greenhouse gas emissions, protecting biodiversity, and preserving fresh water supply. From this perspective, preventing agricultural expansion into forest areas through deforestation bans beyond 2030 could have a significant impact on Canada's contribution to climate change mitigation (Prestele et al., 2016). This would be especially relevant in provinces where agriculture is concentrated and continuously expanding: Alberta, Saskatchewan, Manitoba, and Ontario. In those provinces, agricultural productivity could temporarily improve under moderate climate change through a longer growing season and due to better environmental conditions (higher temperatures and rainfall). Increasing crop productivity is also a key aspect for reducing the impacts of agriculture on forests. Harvesting more tons per hectare has a key role in reducing GHG emissions and agricultural expansion.

At the same time, Canada is a large country, with a population highly concentrated along the US border. This means significant areas of the country have not been extensively disturbed by humans, though some ecoregions are much more deteriorated than others. This is the case of those located in the south, like the Eastern Great Lakes lowland forests ecoregion and others. It is also a country with increasingly strong indigenous land rights over large areas. Compared to other countries, Canada may find it easier to create new protected areas in the near future to reach the 30% goal suggested by the UN Convention on Biological Diversity. The lack of ready access to large territories has already created de facto protected areas, especially in the boreal forest (between 50% and 80% of the total area) (Andrew et al., 2012). Further, the House of Commons created a committee to analyze the future of protected areas that suggested “that the Government of Canada set even more ambitious targets for protected areas than those established in the Aichi Target 11” (Schulte, 2017). This could be included in Canada´s next NDCs, planned for 2025. While the distribution of the population in the territory was not included in both the FABLE Calculator and analysis, we recommend considering it in Canada’s climate strategy as this is not only about biodiversity, it is also about product diversification, vulnerability, and resilience. However, new policies around protected areas and further analysis within the context of FABLE need to account for indigenous land rights over much of the territory that would be considered for protection. Whether formal protected areas administered outside indigenous governance regimes are either feasible or even desirable requires careful consideration.

Additionally, developing a national afforestation program, as called for by the Bonn Challenge, would be a good complement to the increased protection of Canadian ecoregions. Two million hectares of new forests planted in high-value ecoregions, in the context of Canada’s roughly one-billion hectares, is an achievable target and it could have a significant impact on biodiversity. Some initiatives, like the Caribou Habitat Restoration Project, Afforestation Ontario, and the National Greening Program, are already promoting afforestation on degraded lands as a way to recover ecosystem services.

Finally, we note that the analysis conducted was within the context of a dominant economic paradigm that assumes continued economic growth and then views sustainability from the lens of how to reduce future demand and meet that demand with the least impact. Within that context, the Sustainable Pathways are largely based on some changes in demand (e.g. via diet or through lower population growth) and more intensive production (via increased crop yields) with a continued reliance on global markets for both imports and exports. However, there may be other approaches to sustainability worth analyzing. Fundamentally, what does sustainability mean in terms of trade, and economic growth? In our Sustainable High Ambition Pathway, we tried to partially address this issue. For example, we assumed a future more oriented to replacement of first-generation biofuels by locally produced and renewable power for electric vehicles. Additional work could be done examining the role of localizing supply chains within agriculture on both Canada’s SDG attainment as well as spillover effects on other countries. Advancing in this area is one of the main challenges that the FABLE team will have in the near future.

In the coming months, our main challenge will be to engage stakeholders to present and discuss our pathways and projections, while we improve our models, and try to advance in developing alternative paradigms about what sustainability could mean in a context of the ecological and health crisis we are facing today with the emergence of COVID-19.

Annex 1. List of changes made to the model to adapt it to the national context

- Table 3.6 "NationalPdtyScen" was created in the FABLE Calculator to improve estimations about future productivity for rapeseed, barley, wheat and soybeans, according to what specialized paper indicate.
- A new GDP scenario was created (SSP3New) to account for medium levels of economic growth (Sustainable Medium Ambition Pathway).
- A new import scenario was created (Mixed imports) to account for lower imports of some products (corn and sugar), and higher imports of others (mainly vegetables and fruits), according to more local supply chains and healthier diets.
- Two new exports scenarios were created (Sustainable and Sustainable+). The first one is based on medium levels of exports for the main exported crops: rapeseed, barely, wheat, and soybean; according to our export projection. The second scenario is based on the highest level of potential export for those crops.
- A new biofuel consumption scenario was created (National), which projects a progressive reduction in the first-generation biofuel consumption since 2020 to 2030, and its total replacement by electricity (light-duty vehicles).

Annex 2. Underlying assumptions and justification for each pathway

POPULATION Population projection (million inhabitants)		
Current Trends Pathway	**Sustainable Medium Ambition Pathway**	**Sustainable High Ambition Pathway**
Medium speed of population growth that results from low fertility rates of Canadians, which is compensated by a dynamic immigration process. Population grows by 25% by 2050 in comparison to 2015, as cited by Statistics Canada, (2014). Also based on UN DESA (2019)	Low speed of population growth due to higher restrictions for immigrating to Canada. Population grows by 14% by 2050 in comparison to 2015 Based on Bohnert et al. (2015)	Same as the Sustainable Medium Ambition Pathway

LAND Constraints on agricultural expansion		
Current Trends Pathway	**Sustainable Medium Ambition Pathway**	**Sustainable High Ambition Pathway**
We assume that there will be no constraint for agricultural expansion, due to climate change (higher temperatures and better environmental conditions for crops at different zones of the country), higher international demand for commodities, and land availability. Using ESA (2010) and UNEP-WCMC & IUCN (2019), our estimates indicate that, under current land-use trends, agricultural land expands by 26% by 2050,with 84% of new agricultural lands come from deforestation. Also based on Canada's Protected Areas (2019).	Agriculture expansion does not drive deforestation beyond 2030, as new policies ban land use changes that negatively affect forests. Based on ESA (2010), UNEP-WCMC & IUCN (2019) and Canada's Protected Areas (2019)	Same as the Sustainable Medium Ambition Pathway
LAND Afforestation or reforestation target (1000 ha)		
Since deforestation is not a critical issue in Canada, there are no federal goals for afforestation and restoration. We assume that almost no new forests will be planted by 2050, and afforestation will remain as a non-relevant activity in Canada. (NoAfforestation scenario selected)	Programs like the Caribou Habitat Restoration Project, Afforestation Ontario, and the National Greening Program are promoting afforestation on degraded lands as a way to recover ecosystem services. They could reach about 1.000.000 hectares of new forests by 2050 (assuming 2,000 trees per hectare). Based on Government of Ontario (2017), Habitat Conservation Trust Foundation (2020) and Tree Canada (2020) (BonnChallenge scenario selected)	New forests could reach 2,000,000 hectares by 2050 to mitigate climate change, because of successfully implemented programs like the National Greening Program (assuming 1,000 trees per hectare and natural regeneration). (BonnChallenge scenario selected)

BIODIVERSITY Protected areas (1000 ha or % of total land)		
Current Trends Pathway	**Sustainable Medium Ambition Pathway**	**Sustainable High Ambition Pathway**
The "other effective area-based conservation measure", which is considered in the Canadian strategy to reach the Aichi Biodiversity Target, could be ineffective to protect ecosystems, as national parks and other formal protected areas do. This would not increment the share of the terrestrial ecosystems under protection (Lemieux et al., 2019)	The "other effective area-based conservation measure," and complementary measures, will be good enough to adequately protect biodiversity in Canada in the next decades, because they achieve the protection of ecosystem functionality and processes beyond what it has been criticized by different authors (MacKinnon et al., 2015)	Protected areas in Canada could cover 28% of the country by 2050, if different initiatives oriented to increase the protection of ecosystems are successfully implemented. (Andrew et al., 2012; ESA, 2010; Schulte, 2017; UNEP-WCMC & IUCN (2019); Canada's Protected Areas, 2019)

PRODUCTION Crop productivity for the key crops in the country (in t/ha)		
Current Trends Pathway	**Sustainable Medium Ambition Pathway**	**Sustainable High Ambition Pathway**
Negative impacts that result from higher climate variability and extreme weather events will negatively influence crop productivity. In consequence, productivity will increase at a slower pace than in the previous decade.	Advances in crop genetics and better management practices will have positive effects on crop yield, which, would be offset by the negative impacts of climate change. In consequence, crop productivity will increase at the same speed than the previous decade (Assefa et al., 2018; Jing et al., 2017; G. Li et al., 2018; Ray et al., 2013; Thomas & Graf, 2014).	"A better climate" for Canadian crops due to a longer growing season and higher temperatures would increase the productivity of main crops (Lychuk et al., 2017; Qian et al., 2016). This will be strengthened by additional technological advances such as genetic and management improvements (Abberton et al., 2016; Assefa et al., 2018; Bevan et al., 2017; Carpenter, 2010; Jing et al., 2017; G. Li et al., 2018; Ray et al., 2013; Rivers et al., 2015; Smith et al., 2013; Thomas & Graf, 2014).
PRODUCTION Livestock productivity for the key livestock products in the country (in t/head of animal unit)		
Livestock productivity will continue to increase at a similar rate as it was recorded in previous years, in terms of tons of meat, milk and other products per animal. This is because cattle, sheep and goats have already reached an optimum performance.	Livestock productivity will increase greatly by 2050, in terms of tons of product per unit of animal, due to genetic improvements (Mukhopadhyay et al., 2020) and better management practices by farmers.	Same as the Sustainable Medium Ambition Pathway
PRODUCTION Pasture stocking rate (in number of animal heads or animal units/ha pasture)		
Pasture stocking rate will remain stable in the next 30 years, as climate change is not going to produce a positive impact on grass productivity (Li et al., 2013).	"A better climate" in the Canadian prairies and other regions, will increase grass productivity (longer growing season, higher temperatures and enough rain) which will allow to raise more animals per hectares of pastures (Thorpe et al., 2008).	Same as the Sustainable Medium Ambition Pathway
PRODUCTION Post-harvest losses		
This component was not projected in the pathways	This component was not projected in the pathways	This component was not projected in the pathways

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
TRADE Share of consumption which is imported for key imported products (%)		
Canadian imports of the main products will proportionally increase at the same rate as Canadian population increases. In terms of imports per person, it will remain stable.	Canadian imports will moderately increase in the coming decades for the main products due to a higher demand of corn for biofuel (Advanced Biofuels Canada, 2019), and a healthier diet adopted by the Canadian population which results in a larger consumption of fruits and vegetables (Willett et al., 2019).	Canadian imports will decrease at least for corn and raw sugar (Taylor, 2017a, 2017b). The former due of a lower consumption of biofuels by 2040 (Advanced Biofuels Canada, 2019). The latter, due to a lower internal demand resulting from healthier diets. By contrast, vegetable imports will double, and orange juice imports will remain constant, following EAT-Lancet Commission's recommendations.
TRADE Evolution of exports for key exported products (1000 tonnes)		
Canada exports for the main products will increase by 2050, but at a lower rate than It was expected. International competition, biofuel production, and other issues (i.e. political issues) will increase domestic consumption of crops.	Canadian exports for the main products will increase by 2050, as China, U.S., and other important markets for Canadian products will continue to grow in the coming decades, driven by a higher demand of grains and oilseeds (wheat, rapeseed and soybean) to produce biofuels, and feed livestock and poultry (Advanced Biofuels Canada, 2019; Beckman & Nigatu, 2017; Taylor, 2017b). This increment will be high due to the positive relationship between the large production volume, and the relatively low environmental impacts and costs, which differentiates Canada from other producers (i.e. Brazil) Based on Beckman & Nigatu (2017) and dos Santos et al. (2018).	Canadian exports for the main products will increase by 2050, as China, U.S., and other important markets for Canadian products will continue to grow in the coming decades, driven by a higher demand of grains and oilseeds (wheat, rapeseed, and soybean) to produce biofuels and feed livestock and poultry. The rise will be very high for rapeseed and soybean. All these crops would still likely grow under a sustainable intensification approach with trade as they have non-biofuel uses.

FOOD Average dietary composition (daily kcal per commodity group or % of intake per commodity group)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
Dietary composition and intake will have a larger share of processed and ultra-processed food and low-quality calories in Canada (Moubarac et al., 2017). While people slowly understand the importance of having a healthier diet, sedentarism, obesity, and other health issues will increase by 2050. Based on Cooper et al. (2012), Health Canada (2012), Kaczorowski et al. (2016); Martini et al. (2018); Public Health Canada (2017); Rao et al. (2016); Statistics Canada (2017)	People change their diets, reduce ultra-processed food consumption and red meat (to reduce GHG emissions), and increase seeds and vegetables. Educational programs and other initiatives to promote healthier lifestyles have a significant impact on Canadians. Based on Willett et al. (2019)	Same as the Sustainable Medium Ambition Pathway

FOOD Share of food consumption which is wasted at household level (%)

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
The share of wasted food remains stable by 2050. People's behavior concerning this aspect does not change in the coming decades, due to a perceived abundance of food and natural resources in Canada.	The share of wasted food significantly decreases in the coming decades, as people understand the importance of being more efficient in their consumption habits (save money and being friendlier with the environment). Educational programs have an impact on new generations of Canadians. Based on Government of Canada et al. (2019)	Same as the Sustainable Medium Ambition Pathway

BIOFUELS Targets on biofuel and/or other bioenergy use

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
Biofuel demand will remain stable as 2010, due to the lack of international agreements about carbon markets, fossil fuel consumption and climate change mitigation strategies.	Biofuel demand will increase in the coming years based on international agreements about climate change and carbon markets (Advanced Biofuels Canada, 2019). However, new/more efficient technologies will displace biofuels after 2030, thus limiting its demand.	Demand for liquid biofuels will decrease over time as incentives put forth by the federal government to promote zero-emissions vehicles make these fuel sources obsolete in the near future (NRCAN, 2020). We expect demand for these products to fall substantially by 2030.

Canada

CLIMATE CHANGE Crop model and climate change scenario

Current Trends Pathway	Sustainable Medium Ambition Pathway	Sustainable High Ambition Pathway
Average temperature increases by 6.0 Celsius degrees, according to the HadGEM2-ES climate model, the GEPIC crop model, without fertilization effect. Despite of this global change, aspects like growing season, temperature rainfall, and others will remain stable for Canada.	Average temperature increases by 2.6 Celsius degrees, according to the HadGEM2-ES climate model, the GEPIC crop model, without fertilization effect. Region climates are going to be affected in most of the Canadian provinces and territories, with positive impacts on crops (longer growing season and higher average temperatures will increase crop productivity, see crop productivity panel). Similar effects can be expected in northern territories. In general, there will be less snow and ice, and more rain, which could negatively affect forestry operations.	Average temperature increases by 2.6 Celsius degrees, according to the HadGEM2-ES climate model, the GEPIC crop model, without fertilization effect. Under this scenario, climates do not change to such a large extent in Canada. This will allow for a longer growing season as well as better temperatures and rainfall for most crops.

Annex 3. Correspondence between original ESA CCI land cover classes and aggregated land cover classes

Original land cover class from ESA CCI	Aggregated land cover class
Grassland	Grassland
Water	Not Relevant
Shrubland	Other Land
Cropland_rainfed	Cropland
Herbaceous	Grassland
Tree_or_shrub	Forest
Cropland_irrigated	Cropland
Mosaic_crop_natveg	Cropland
Mosaic_natveg_crop	Cropland
Tree_BL_EVG_sup15pc	Forest
Tree_BL_DEC_sup15pc	Forest
Tree_BL_DEC_sup40pc	Forest
Tree_BL_DEC_15_40pc	Forest
Tree_NL_EVG_sup15pc	Forest
Tree_ML	Forest
Mosaic_tree_shrub_herba	Forest
Mosaic_herba_tree_shrub	Grassland
Shrubland_DEC	Other Land
Sparse_vege_low15pc	Other Land
Sparse_herba_low15pc	Other Land
Tree_flooded_fresh	Forest
Tree_flooded_saline	Forest
Shrub_Herba_flooded	Other Land
Urban	Urban
Bare	Not Relevant
Tree_NL_EVG_sup40pc	Forest
Lichens	Other Land
Sparse_shrub_low15pc	Other Land
Conso_bare	Not Relevant
Snow_ice	Not Relevant
Shrubland_EVG	Other Land
Sparse tree	Forest
Unconso_bare	Not Relevant
Tree_NL_EVG_15_40pc	Forest
Tree_NL_DEC_sup15pc	Forest
Tree_NL_DEC_sup40pc	Forest

Annex 4. Overview of biodiversity indicators for the current state at the ecoregion level[4]

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with >10% Natural Vegetation within 1km² (%)
0	Rock and Ice	1221.0	26.4	99.8	26.4	73.6	0	0
333	Eastern Canadian Forest-Boreal transition	31868.2	9.1	75.8	10.3	89.7	537.0	63.5
334	Eastern Great Lakes lowland forests	8771.0	1.6	16.7	4.5	95.5	5152.0	28.4
335	Gulf of St. Lawrence lowland forests	3539.9	3.6	50.5	6.2	93.8	487.0	48.8
338	New England-Acadian forests	16295.0	7.1	58.9	11	89	1115.9	63.1
342	Southern Great Lakes forests	2495. 8	0.8	8.3	7.3	92.7	1950.2	11.5
344	Western Great Lakes forests	7450.9	12.8	65.9	15.5	84.5	264.6	53.9
345	Alberta-British Columbia foothills forests	12135.0	1.5	77.8	1.8	98.2	554.6	53.9
349	British Columbia coastal conifer forests	10781.9	21.3	93.3	22.5	77.5	14.4	87.2
350	Central British Columbia Mountain forests	13972.9	6.3	82.7	7.4	92.6	135.6	78.4
351	Central Pacific Northwest coastal forests	3495.1	18.6	82.8	19.6	80.4	0.4	100
355	Fraser Plateau and Basin conifer forests	10445.0	14.9	73.8	19.5	80.5	198.5	80.1
358	North Cascades conifer forests	639.0	29.7	85	34.5	65.5	10.9	63.3
361	Northern Rockies conifer forests	18313.7	30	89.4	33.3	66.7	111.7	80.1
362	Okanogan dry forests	5257.1	6.5	67.4	9.1	90.9	141.0	70.3
364	Puget lowland forests	1867.6	11.1	66.2	15.7	84.3	158.2	41.3
365	Queen Charlotte Islands conifer forests	960.8	47.7	87	49.7	50.3	0	0
370	Central Canadian Shield forests	27135.5	9.2	81.8	10.3	89.7	184.3	74.8

4 The share of land within protected areas and the share of land where natural processes predominate are percentages of the total ecoregion area (counting only the parts of the ecoregion that fall within national boundaries). The shares of land where natural processes predominate that are protected or unprotected are percentages of the total land where natural processes predominate within the ecoregion. The share of cropland with at least 10% natural vegetation is a percentage of total cropland area within the ecoregion.

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with >10% Natural Vegetation within 1km² (%)
373	Eastern Canadian forests	46073.3	8.4	87.4	9.2	90.8	222.2	46.9
374	Eastern Canadian Shield taiga	75288.3	9.6	92.8	9.7	90.3	0	0
375	Interior Alaska-Yukon lowland taiga	2066.8	43.9	98.3	44.5	55.5	0	0
376	Mid-Canada Boreal Plains forests	56846.4	8	63.9	10.6	89.4	10228.1	25.4
377	Midwest Canadian Shield forests	75547.0	10.2	87.6	10.8	89.2	10.6	95.7
378	Muskwa-Slave Lake taiga	29791.6	21.5	91.9	22.8	77.2	11.6	79.4
379	Northern Canadian Shield taiga	63056.3	6.4	86.1	7	93	0	0
380	Northern Cordillera forests	16888.0	26.4	99.3	26.6	73.4	2.4	96.9
381	Northwest Territories taiga	33261.5	5.9	84	6.6	93.4	0	0
382	Southern Hudson Bay taiga	37201.0	12.2	98.3	12	88	0	0
383	Watson Highlands taiga	23823.6	4.4	98.4	4.4	95.6	18.8	83.1
386	Canadian Aspen forests and parklands	19255.1	4.8	4.8	42.3	57.7	15672.2	10.9
394	Montana Valley and Foothill grasslands	1488.1	0.3	1.7	10.4	89.6	1078.1	20.3
396	Northern Shortgrass prairie	22371.2	8.2	3.8	53	47	14576.4	16.6
397	Northern Tallgrass prairie	3781.7	1.7	9.3	13.5	86.5	2543.1	14.1
398	Palouse prairie	79.3	16.2	57.9	22.5	77.5	8.8	50.1
405	Alaska-St. Elias Range tundra	2387.7	89.2	57.6	81.4	18.6	1.6	98
408	Arctic foothills tundra	546.9	44.2	95	45.1	54.9	0	0
411	Brooks-British Range tundra	2671.0	27.4	99.8	27.4	72.6	0	0
412	Canadian High Arctic tundra	63315.4	9.5	79.2	9	91	0	0
413	Canadian Low Arctic tundra	82959.1	16.6	83.4	18.7	81.3	0	0
414	Canadian Middle Arctic Tundra	95827.2	6.7	87.5	7.4	92.6	0	0

Canada

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with >10% Natural Vegetation within 1km² (%)
415	Davis Highlands tundra	9451.4	29.5	62.5	23.3	76.7	0	0
416	Interior Yukon-Alaska alpine tundra	3848.3	0	97.9	0	0	0.4	88
419	Ogilvie-MacKenzie alpine tundra	29104.4	11.8	99.7	11.8	88.2	0.0	100
420	Pacific Coastal Mountain icefields and tundra	2456.9	21.7	84.7	8.2	91.8	0.0	100
421	Torngat Mountain tundra	3196.6	41.6	92.1	42.5	57.5	0	0

Units

°C – degree Celsius

% – percentage

/yr – per year

cap – per capita

CO_2 – carbon dioxide

CO_2e – greenhouse gas expressed in carbon dioxide equivalent in terms of their global warming potentials

g – gram

GHG – greenhouse gas

Gt – gigatons

ha – hectare

kcal – kilocalories

kg – kilogram

km^2 – square kilometer

km^3 – cubic kilometers

m – meter

Mha – million hectares

Mm^3 – million cubic meters

Mt – million tons

t – tonne

TLU – Tropical Livestock Unit is a standard unit of measurement equivalent to 250 kg, the weight of a standard cow

t/ha – tonne per hectare, measured as the production divided by the planted area by crop by year

t/TLU, kg/TLU, t/head, kg/head- tonne per TLU, kilogram per TLU, tonne per head, kilogram per head, measured as the production per year divided by the total herd number per animal type per year, including both productive and non-productive animals

USD – United States Dollar

W/m^2 – watt per square meter

yr – year

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