**November 29, 2017**

**Comments to Senate Standing Committee on Agriculture and Forestry by the Parliamentary Budget Officer**

Thank you for this opportunity to follow up to the Committee on the comments made during the meeting on November 9, 2017.

This note provides more detailed answers to the questions and issues raised during the meeting concerning Canada's agriculture-based greenhouse gas (carbon dioxide equivalent, hereafter "carbon", CO2e) emissions. It also provides more material (regarding agriculture) than was in the original PBO report: Canada's Greenhouse Gas Emissions: Developments, Prospects and Reductions.

To respond to the most specific question asked by Senator Mercer, the current practice of no-till, or conservation tillage, is resulting in a measured reduction of 1.5 million tonnes of carbon per year. This is because no-till results in a reduction of nitrous oxide emissions from fertilizer application. To be more precise, croplands in western Canada (prairies) lose less nitrogen when not tilled. In eastern Canada, they lose more nitrogen. The balance has been for Canada's soils to gain nitrogen, and be net carbon sinks. This adjustment can continue into the future and be expanded as more lands are brought into no-till practice.

Western Canada's croplands are also carbon sinks when they are not tilled because roots, etc, add to soil carbon. In eastern Canada, they are carbon sources when not tilled. In 2015 Canada's croplands captured some 14 million tonnes of carbon largely from the practice of no-till (apart from the 1.5 million tonne mentioned above as coming from lower nitrogen loss). Since conventional tillage is still practiced on some 13% of seeded cropland in western Canada, there is capacity to prolong and extend that net sink. But because soils eventually reach equilibrium in the carbon they capture and that which they release, the ability of no-till to provide sinks has limits.

Currently, however, this latter sink is not formally recognized in Canada's emissions. When Canada reported its emissions as 722 megatonnes for 2015, it did not include sequestration in soils from tillage practice. Even though Canada has announced its intention to count such sinks, it has not yet started to do so.

**Emission sources**

The pan-Canadian Framework announced by the federal government largely exempts agriculture from carbon pricing.[1] Some provisions in that program are intended to encourage carbon storage in soils, and have agriculture contribute to biofuels, but details concerning those proposals are currently not available.

Carbon emissions in Canada's agricultural sector represent some 10 percent of all emissions. They come primarily from livestock (5 percentage points) and crops (3 percentage points), but also from on-farm energy and transport (2 percentage points).

For livestock, emissions come from two sources where methane (CH4) and nitrous oxide (N2O) are released. Both gases are considerably more potent by weight than carbon as warming agents. Emissions come from:

(1) enteric fermentation during digestion (primarily belching from cattle); and,

(2) manure management, primarily from cattle and swine.

With crops, emissions are related to soil management with the direct and indirect emissions of N2O (as well as some methane and nitrous oxides). Canada's main crops are grains (wheat, alfalfa, and barley) and oil seeds (canola, soybeans and lentils).

Direct N2O emissions are generated by:

(1) the use of inorganic nitrogen fertilizers;

(2) application of manure and slurry on cultivated fields;

(3) decomposition of crop residues; and,

(4) soil tillage activity.

Indirect N2O emissions are generated by the volatilisation and leaching of:

(1) atmospheric volatilisation of fertilizers (both inorganic and manure);

(2) runoff and leaching of fertiliser (inorganic, manure, and crop residue).

1 www.canada.ca/content/dam/themes/environment/documents/weather1/20170113-1-en.pdf

**Reducing emissions**

To reduce carbon emissions, or their equivalents, either an explicit price on carbon (e.g. a carbon tax), or an implicit price in the form of regulatory actions is needed to create the appropriate incentives. The challenge when using regulatory tools is to ensure that they impose the same cost as a carbon price in other sectors. This is not a question of fairness; it is a necessary criterion to ensure that the cost to the economy as a whole is kept to a minimum.

The challenge when using a carbon price is that emissions are calculated based on averages – such as that per animal, or per unit of fertilizer used. Unlike those for emissions from fossil fuels, *emission factors* for agriculture are calculated over a wide variation of observations. How crops are grown and livestock raised, including what is done with waste for both, and how the soil is treated prior to seeding, can have a significant impact on emissions.

Canada typically applies emission factors for different crops and livestock that are regionally adjusted. But the farm-to-farm variation is not accounted for (it would be costly to do so), so only emissions that are averaged across those regional farms are reported. This may even be biased due to year-to-year variation in climatic conditions, and prices affecting farmer's behavior. So, the uncertainty in agricultural emissions – such as those reported in the National Inventory Report (NIR) – is significantly greater than it is with fossil-fuel emissions.

The Canadian government's pan-Canadian Framework on climate change requires that fossil-fuel users face a price for emissions, and industrial facilities face performance standards for their emissions. For illustrative purposes, the analysis here uses a price of $25 per tonne of CO2e. This is half what the final price of the framework is intended to reach – it starts at $10 in 2018, then goes up by $10 per year until it reaches $50.

The cost per farm of a $25 carbon price is significant for both crop and livestock farmers (Table 1, columns 6, 7, and 9; Table 2, column 4; and, Table 3).

**Cost of reducing emissions**

Since cattle and swine cause most livestock emissions, they will be the focus here for succinctness. The reported estimates of emissions per farm (Table 1) are based on an average national rate of emissions for dairy cows, and a national average for non-dairy cows. To the extent that any farm is operating more efficiently (in terms of methane and manure-based emissions) than the average, then their cost should be lower. For example, using alfalfa or feed supplements, as well as efficient manure management and/or composting, would mean that their emissions are below the average.

**Table 1. Cattle farms and swine**

| | Cattle | | | | | | | Swine |
|---|---|---|---|---|---|---|---|---|
| | Average farm size(1) | | Emissions per farm (tCO2e) | | Cost per farm(2) | | Total cattle and calves (1000) | Cost per farm(3) |
| | non-Dairy | Dairy | non-Dairy | Dairy | non-Dairy | Dairy | | |
| Alberta | 94 | 97 | 173 | 463 | $4,330 | $11,566 | 5,207 | $3,864 |
| British Columbia | 63 | 110 | 116 | 529 | $2,902 | $13,215 | 659 | $315 |
| Manitoba | 77 | 98 | 140 | 469 | $3,510 | $11,724 | 1,103 | $16,279 |
| New Brunswick | 26 | 79 | 48 | 380 | $1,201 | $9,507 | 68 | $1,536 |
| Newfoundland | 7 | 156 | 13 | 746 | $333 | $18,654 | 10 | $542 |
| Nova Scotia | 23 | 81 | 41 | 386 | $1,035 | $9,651 | 76 | $363 |
| Ontario | 26 | 71 | 47 | 339 | $1,171 | $8,486 | 1,624 | $4,098 |
| Prince Edward Island | 30 | 70 | 55 | 335 | $1,385 | $8,375 | 59 | $3,001 |
| Quebec | 41 | 62 | 75 | 298 | $1,877 | $7,446 | 1,132 | $7,411 |
| Saskatchewan | 89 | 94 | 163 | 449 | $4,080 | $11,217 | 2,592 | $4,952 |
| **Canada** | **71** | **73** | **131** | **349** | **$3,271** | **$8,716** | **12,531** | **$5,367** |

**Source**: Agriculture Census (2016), National Inventory Report (2017).
**Note**: These numbers are approximate since they combine agriculture census data for 2016 with emission data for 2015. Nonetheless, alternative data sources suggest that Canada's cattle population was virtually unchanged between 2015 and 2016, while the hogs population increased by 3.6%. So the cost per swine farm could be 3 to 4 % higher.
(1) Includes all cattle (steers, heifers and cows), calves, and bulls.
(2) Using an average lifespan of cattle of 1.5 years, a $25 carbon tax adds $69 for a beef cow, and $180 for a dairy cow.
(3) A $25 carbon tax adds $3.2 for each swine based on standard "Canada-wide" average manure treatment.

There is considerable variation in the size of farms, which leads to a large divergence of cost per farm across Canada (columns 2 and 3). This is particularly true of swine farms as reflected in the last column. Manitoba, for example, has on average more than 5,000 swine per farm.[2] In British Columbia it is less than 100.

The other main source of agricultural emissions are crops (Table 2). Given the substantial variation in the type of crops grown in each region, national averages need to be treated carefully. For the table, crops have been distinguished by production per acre (tonnes, Table 1-1 in the Annex), so residues by crop – and their emissions – are distinguished by crop and province. For simplicity, harvest of plant residue has not been accounted for, so emissions would be lower on farms where it is done.

[2] Estimated from Census of Agriculture data reporting number of swine and number of farms.

However, for fertilizer use, no distinction was made between crops. It is averaged provincially. Crops and farms that use more (less) than the provincial average, would emit more (less) carbon equivalent than is indicated in the Table. For reference, given a nitrogen application rate of 60kg per hectare, the cost would increase by $2.9 per acre for those who apply it at that rate.[3]

The crop mix (and to some extent the different farming techniques between provinces) are reflected in the emissions per acre. They go from a low of 0.18 tonnes per acre in Saskatchewan, to a high of 7.13 in Newfoundland. Scale is an obvious factor since those two provinces are also the largest and smallest producers (by crop area), respectively. But other factors are also important. In Newfoundland, for example, the main factor is extensive use of techniques to counter the acidity of soils – they account for almost two thirds of its emissions.

[3] Using a nitrogen to nitrous oxide conversion of 1 percent.

**Table 2. Croplands**

| | Average seeded farm area (acres) | Average emissions (ktCO2e) | Average cost per farm | Emissions per acre (tCO2e) | | |
|---|---|---|---|---|---|---|
| | | | | **Total** | ***of which, from inorganic fertiliser*** | ***of which, from crop residue*** |
| Alberta | 855 | 6,800 | $6,631 | 0.31 | *0.13* | *0.07* |
| British Columbia | 93 | 450 | $1,685 | 0.72 | *0.14* | *0.08* |
| Manitoba | 995 | 3,300 | $7,966 | 0.32 | *0.17* | *0.07* |
| New Brunswick | 153 | 270 | $6,472 | 1.70 | *0.28* | *0.20* |
| Newfoundland | 24 | 32 | $4,211 | 7.13 | *0.28* | *0.24* |
| Nova Scotia | 72 | 130 | $2,664 | 1.48 | *0.28* | *0.16* |
| Ontario | 210 | 4,200 | $2,921 | 0.56 | *0.12* | *0.14* |
| Prince Edward Island | 323 | 193 | $5,403 | 0.67 | *0.28* | *0.19* |
| Quebec | 187 | 3,500 | $5,230 | 1.12 | *0.21* | *0.21* |
| Saskatchewan | 1375 | 6,800 | $6,224 | 0.18 | *0.12* | *0.04* |
| **Canada** | 648 | **25,675** | $5,094 | 0.31 | *0.13* | *0.07* |

**Source**: Agriculture Census (2016), National Inventory Report (2017).

**Note**: These numbers are approximate since they combine agriculture data for 2016 with emission data for 2015. Since Canada's croplands declined by 0.9% between the 2011 and 2016 census, the 2015 measure of croplands is approx. 0.18% less than 2016. The approximation should thus only have small errors that are unlikely to affect any conclusions. The conversion of product per acre (Annex Table 1-1) to crop residue was done using Janzen, et al (2003). For the columns outlining inorganic fertiliser (column 6) and crop residue (column 7), the calculation is done on the basis that all crops use nitrogen fertiliser and leave a crop-specific residue. Emissions would be adjusted for farms that don't use inorganic fertilizer and/or remove crop residue.

The third main source of emissions is from on-farm energy and transport. Saskatchewan and Alberta have the highest energy/fuel use and would have the largest impact from carbon pricing of fuels – given their large-scale farms. The pan-Canadian Framework exempts gasoline and diesel fuel used in agriculture from the carbon price, but since the use of fuel is extensive, the impact of a reversal of that exemption would be substantial (Table 3).

**Table 3. Cost of on-farm energy and transport emissions ($25 per tCO2e tax)**

| | Alberta | British Columbia | Manitoba | New Brunswick | Newfoundland | Nova Scotia | Ontario | Prince Edward Island | Quebec | Saskatchewan | Canada |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Average cost per farm** | $2,030 | $856 | $1,690 | $1,109 | $909 | $719 | $1,300 | $820 | $951 | $3,693 | $1,801 |

**Source**: Agriculture Census (2016), National Inventory Report (2017).
**Note**: These numbers are approximate since they combine agriculture data for 2016 with emission data for 2015. Since Canada's farms declined by 6% between 2011 and 2016, the results reported in the table are likely understated by 1% to 1.5%.

### Impact of carbon pricing

To be clear, these results only indicate the scale of incentives that farmers would be facing with carbon pricing. Precision is limited by the fact that they reflect averages at provincial scales, whereas the farm-to-farm variation can be large.

Moreover, even if a policy were implemented, the results do not imply that money on that scale would be lost to farmers. Responses to carbon pricing would make the ultimate cost lower since farmers would reduce emissions and the cost of those reductions would generally be less than $25 per tonne.

This highlights that measuring emission reductions will be important to determine what cost (if any) would be left to farmers. Again, this is complicated by the use of emission factors. Abatement would potentially have to be measured at a farm scale. And emission reductions would have to be demonstrable so they could be reported in Canada's National Inventory Report. That sets a high hurdle. Two possibilities for achieving that include either: regulations that have known effects in changing emissions; or, imposing a carbon price based on the emission factors, and then crediting the farmer for abatement from activities relative to the norm embodied in the emission factor – e.g. composting of manure, or supplementing foods, etc.

The essential element of an emission abatement policy is to provide incentives for farmers to do so. The final cost of that policy to farmers is largely independent of that objective since numerous options exist to mitigate the effect on farming income (e.g. revenue recycling).

Returning the carbon tax to farmers through reductions in other taxes (e.g. income taxes, etc), as Alberta and British Columbia do with their carbon taxes, is one means of illustrating that independence.

Altering the price between carbon-producing activities and carbon-neutral activities is another (e.g. Skolrud and Galinate, 2017). In that case, revenues generated by pricing carbon emissions could be used to fund investments by farmers in equipment that would reduce emissions. Or, in the case of crop farming, lower the cost of fertiliser additives such as nitrification inhibitors to slow the release nitrogen. These examples are illustrative of what is possible, and are not comprehensive enough to constitute policy recommendation.

The potential need for these complementary measures is underscored by the fact that agriculture produces commodities that trade on world markets. There is thus limited ability for farmers to pass on any additional costs to consumers. Abatement of emission-causing processes would therefore have to be the main response by farmers to a carbon price. If there is not certainty that other countries are undertaking similar policies, Canadian farmers could be disadvantaged.

**Actions that reduce carbon emissions**

A list of actions that reduce emissions would include (not exhaustive),

1) Sequestering carbon in agricultural soils by reducing tillage of croplands.

    - In the Prairie Provinces, conventional tilling leads to both greater nitrous oxide release, as well as soil carbon loss. No-tillage farming reduces greenhouse gas emissions from fertiliser, and captures carbon in the soil.

    - In 2015, convention tilling was still practised on more than 13% of seeded croplands in the prairies. Continuing to leave soils untilled and adding additional acreage to them has the potential to continue carbon sequestration into the future – though at a declining rate as soils approach equilibrium.

2) Reducing nitrous oxide emissions through more efficient use of nitrogen fertiliser,

    - Fertiliser use is a main source of emissions, particularly in the prairies. Greater use of slow-release nitrogen fertiliser – so more of it was absorbed by the plant – could reduce emissions. Since nitrification inhibitors add to the cost of fertiliser, incentives would have to be created for their widespread adoption – though potentially accounting for competitive pressures in international markets.

    - Creating incentives for greater use of fertiliser injection is another potential improvement in efficiency.

3) Improve livestock growth efficiency so that emissions are lower over the life of each livestock

   - This involves selection of feed to improve digestion (e.g. optimal use of alfalfa); feed additives that minimise methane generation (e.g. recent trials with bromoform from seaweed, optimal use of higher energy content feeds); "precision feeding" that gets the most growth out of each pound of feed; and selective breeding of animals with higher efficiency digestion. Indeed, even providing incentives to maintain the health of the herd at maximum levels would improve farm efficiency and reduce emissions since each pound of feed will produce more of the final product.

4) Reducing $CH_4$ and $N_2O$ emissions from manure management (storage, treatment, and spreading, as well as animal housing and yards),

   - This includes: preference for slurry-based housing rather than straw-based; controlling livestock diet so it is animal specific, again "precision feeding"; covering manure lagoons; maintaining manure at lower temperatures; timing and method of manure application in fields so there is maximum absorption by crops – just as the crop needs it, at the right "micro" doses, and only when soil is dry; implementing emission capture at manure handling facilities.

   - Composting of manure is also a good mechanism for reducing emissions.

5) Substituting renewable fuels for gasoline, diesel fuel and natural gas used on the farm,

   - Includes the use of biofuels as well as electric-powered equipment and vehicles (increased demand would accelerate their development).

This list is not exhaustive. But it points out that the agricultural sector can reduce emissions. Some of the actions may cost more than $25 per tonne of carbon abated, but some of them may cost less. Carbon pricing leaves the decision concerning which actions to undertake to individuals or firms.

Finally, creating ammonia (for nitrogen fertilizer) from feedstocks other than natural gas would reduce emissions, but not in the agricultural sector. Those technologies exist, but they are more expensive than using natural gas. In current reporting standards, the chemicals sector is responsible for the process emissions from ammonia production, and emission reductions would thus occur within that sector. If a policy framework such as the pan-Canadian Framework were to make the manufacturers responsible for the eventual emissions from the use of their products, then those manufacturers would face the cost of both the process emissions, as well as the use emissions. If they were to pass along those costs to farmers, this would still increase the cost of inorganic fertiliser. When applied at the rate of 60kg of nitrogen per hectare (illustrative of wheat and cereals), a $25 carbon tax that was fully passed through would lead to costs on the scale of $2.9 per acre.

# Annex 1

## Table 1-1. Production per acre (tonnes)

| | All wheat | Canola | Tame hay | Barley | Lentils | Soybeans | Corn (grain) | Oats | Corn (fodder) | Peas (dry) |
|---|---|---|---|---|---|---|---|---|---|---|
| Alberta | 1.48 | 1.03 | 1.62 | 1.38 | 0.88 | | 2.55 | 0.82 | 14.05 | 0.51 |
| British Columbia | 1.40 | 0.86 | | 1.05 | | | | 0.79 | 20.61 | 0.46 |
| Manitoba | 1.43 | 0.87 | 1.71 | 1.50 | | 1.08 | 3.39 | 1.28 | 15.86 | 0.42 |
| New Brunswick | 1.27 | | | 1.42 | | 0.98 | 2.97 | 1.04 | 12.99 | |
| Newfoundland | | | | | | | | | | |
| Nova Scotia | 1.85 | | | 1.31 | | 1.17 | 2.94 | 0.78 | 16.36 | |
| Ontario | 2.34 | 0.93 | 2.12 | 1.31 | | 1.25 | 3.98 | 1.02 | 18.18 | |
| Prince Edward Island | 1.32 | | | 1.42 | | 0.93 | 3.05 | 1.03 | 14.77 | |
| Quebec | 1.38 | 0.94 | 2.38 | 1.42 | | 1.30 | 4.27 | 0.99 | 17.46 | |
| Saskatchewan | 1.20 | 0.96 | | 1.37 | 0.52 | 0.85 | | 1.13 | 11.64 | 0.45 |
| **Canada** | 1.37 | 0.97 | 1.67 | 1.38 | 0.56 | 1.19 | 3.98 | 1.05 | 16.59 | 0.48 |

**Source**: Agriculture Census (2016), National Inventory Report (2017).
**Note**: These numbers are approximate since they combine agriculture data for 2016 with emission data for 2015. These crops account for about 95% of Canada's crop production by weight.