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CARBON SEQUESTRATION BY AGRICULTURAL SOIL

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INTRODUCTION

According to the greenhouse effect theory, the discharge into the atmosphere of large quantities of carbon dioxide (CO_2) and, equally important, other trace gases will eventually warm the planet. The Earth's climate has always been evolving, yet many climatologists, scientific researchers and environmental lobby groups believe that increasing concentrations of the gases that produce the greenhouse effect in the atmosphere will lead to temperature increases big enough to bring about major climatic changes.(1) According to the draft of the third report by Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC) sponsored by the United Nations, increasing concentrations of man-made greenhouse gases have contributed significantly to global warming over the past 50 years.(2)

Climate change presents adaptation challenges for Canadian agriculture that are expected to become more apparent over time. For example, the sector may have to deal with increased weather variability and higher risks of droughts, flooding and new insect infestations. Opportunities may also arise from climate change, notably a northward extension of crop lands and grazing zones.(3)

The international community has repeatedly undertaken to reduce greenhouse gas emissions in order to slow the process of climate change. In 1997, after the Kyoto Protocol was negotiated, Canada undertook to reduce its emissions by 6% relative to 1990 levels. In 1997, agriculture accounted for 9% of greenhouse gas emissions in Canada, or 61.4 million tonnes, primarily carbon dioxide (CO_2), nitrous oxide and methane.(4)

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(1) Christine Labelle and William Murray, *Greenhouse Gases and Climate Change*, Ottawa: Parliamentary Research Branch, Library of Parliament, revised 25 June 1999.

(2) "La température de la planète devrait se réchauffer de 1,5 °C à 6 °C en 2100, affirment les scientifiques de l'IPCC", *Le Monde*, 2 November 2000.

(3) Agriculture and Agri-Food Canada website, taken from a page available at the following address: http://www.agr.ca/policy/environment/eb/public_html/ebe/climate.html, updated 27 July 1999.

(4) Robert Hornung, Pembina Institute, Presentation at a Library of Parliament workshop on climate change, 29 September 2000.

This document focuses on the role of agricultural soil in CO_2 emissions. The first part describes the process of soil carbon sequestration and how that process can help reduce agricultural CO_2 emissions. The second part looks at ways the agriculture industry can create "carbon sinks."

SOIL CARBON SEQUESTRATION

A. CO_2 Emissions From Canadian Farms

In agriculture, there are three main sources of carbon dioxide emissions: changes that affect soil carbon reserves; CO_2 released through the use of fossil fuels on farms; and indirect emissions related to the use of fossil fuels to produce pesticides, fertilizers, etc. The following table shows estimated CO_2 emissions from various sources in the Canadian agricultural industry.

Table 1

Estimated CO_2 Emissions by the Canadian Agricultural Industry

	1981	1986	1991	1996
	(millions of tonnes of CO_2)			
Soils	7.7	7.3	5.1	1.8
Fuels used on farms	9.5	7.7	8.1	9.5
Indirect emissions(5)	13.7	14.7	14.6	16.3
Total emissions attributable to agriculture	30.9	29.7	27.8	27.6

Source: R.L. Desjardins in *The Health of Our Air: toward sustainable agriculture in Canada*, Agriculture and Agri-Food Canada, Research Branch, 1998.

According to the data in Table 1, CO_2 emissions from agricultural soil decreased from 7.7 million tonnes in 1981 to 1.8 million tonnes in 1996; they are believed to be virtually zero today.(6) The reasons for this trend are stated in the following sections.

(5) Indirect emissions include the release of CO_2 during the manufacture and transportation of fertilizer and other inputs, the manufacture of farm machinery, the generation of electricity, etc.

(6) Terence McRae, Agriculture and Agri-Food Canada, *An Agri-Environmental Perspective on Multifunctionality*, presentation at the general meeting of the Canadian Federation of Agriculture, 23 February 2000, workshop on multifunctionality and precautions.

B. The Carbon Cycle in Agriculture

To understand CO_2 emissions from soil, it is important to have some idea of the carbon cycle in farm systems. Generally, CO_2 in the atmosphere is absorbed by plants, which transform it into carbohydrates, cellulose and other sugars. Each plant uses some of the carbon compounds to meet its energy needs and converts them back into CO_2. Some of the carbon remaining in the plant is then removed from the system when the plant is harvested; the rest ends up in the ground and is transformed into CO_2 again by microbes in the soil. This cycle is identical in all crop systems, but the quantities of CO_2 involved vary depending on climate, soil and type of plant. The cycle is slightly more complex on farms where animals are raised because instead of being removed from the system, a considerable proportion of the plant matter is used as bedding or feed. Some of that carbon is released by the animals in the form of CO_2, some is removed in the form of animal products (meat, for example), and a significant quantity is returned to the ground in the form of manure.

On land that has undergone few changes over the years (a natural prairie, for example, or land that has been farmed the same way for many decades), there is a balance between the carbon captured by the plants and the carbon returned to the atmosphere; as a result, the quantities of carbon stored in the soil do not change.(7) However, a change in land management disrupts the carbon cycle. For example, when forests and natural prairies are cleared for farming, a large quantity of the original organic matter is transformed into CO_2 and released into the atmosphere. When the land is then used for crops for several decades, the quantities stored in the soil become stable once again. However, when farming practices are changed to increase the organic carbon content of the soil, the reverse occurs: the soil captures more CO_2 than it emits, which means that CO_2 is removed from the atmosphere and stored in the soil. This process is called carbon sequestration: the term “soil sink” is used to mean agricultural soil that accumulates carbon.(8) Figure 1 illustrates the changes that occur at various times in carbon reserves in agricultural soil.

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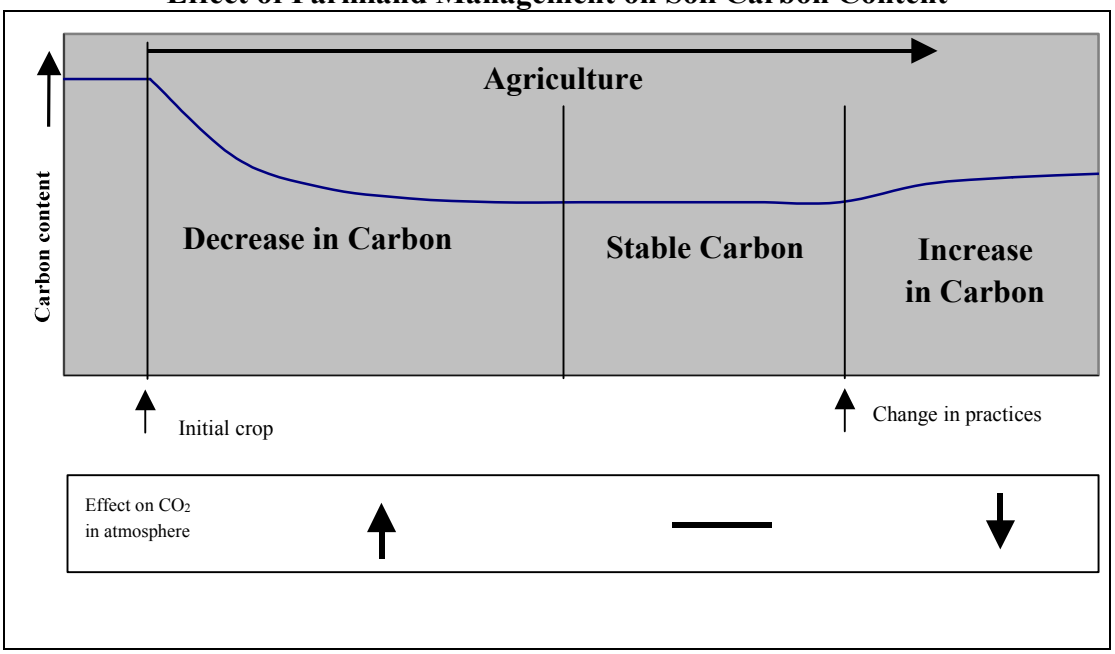
(7) Agriculture and Agri-Food Canada, Research Branch, *The Health of Our Air: toward sustainable agriculture in Canada*, 1998.

(8) Generally, a “carbon sink” is an activity that removes CO_2 from the atmosphere: there are “soil sinks” (carbon sequestration by soil) and “forest sinks” (carbon sequestration by a growing forest).

Figure 1

Effect of Farmland Management on Soil Carbon Content



Source: Adapted from R.L. Desjardins in *The Health of Our Air: toward sustainable agriculture in Canada*, Agriculture and Agri-Food Canada, Research Branch, 1998.

A country could therefore use the carbon sequestration capacity of its agricultural soil to reduce greenhouse gas emissions. That capacity is not unlimited, however, because the carbon reserves in the soil stabilize again after a number of years of unchanged land management.

C. Farming Practices that Allow Soil to Sequester Carbon

The long-term carbon retention capacity of soil depends on sound land management. Soil sinks cannot be created unless practices are adopted that increase the carbon content of the soil. Those practices, which can vary depending on the type of soil and climate, include:

- a decrease in the amount of land left fallow;
- the use of direct drilling, which does not disturb the soil as much and reduces the amount of CO_2 released into the atmosphere;
- the use of legumes and/or grasses in crop rotation;
- the conversion of marginal farmland to perennial grasses or trees;

- the use of rotation grazing and high-intensity short-term grazing;
- the planting of shrubs and trees as windbreaks; and
- the restoration of wetlands.

Many management methods aimed at storing carbon in soil sinks also contribute to environmental sustainability. Increasing the organic matter content of soil helps improve the soil's agronomic capabilities. It also produces better soil and better crops, improves water conservation, reduces erosion, and improves wildlife habitat and species protection, leading to greater biodiversity.(9)

These methods can also make farms more profitable. For example, minimum tillage reduces the need for machinery and therefore lowers production costs.(10)

D. Soil Carbon Sequestration in Canada

Historical observations in Canada confirmed by mathematical models have shown that soil carbon reserves decreased quickly in the early 20th century as a result of the cultivation of a large amount of unused land. Those carbon losses gradually diminished as the soil achieved a new state of stability. The losses almost completely stopped in the mid-1990s.(11)

In 1998, Agriculture and Agri-Food Canada (AAFC) projected that agricultural soil would cease to be a source of CO_2 before 2001 and would store between 0.5 and 0.7 million tonnes of carbon a year beginning in 2010.(12) This trend will continue only until the soil reaches a new balance and only if practices that foster increased carbon content are maintained.(13)

There is still some uncertainty over how to quantify the CO_2 that is actually removed from the atmosphere and stored in soil. AAFC's estimates are based on the CENTURY model, which uses certain scientific theories about soil, climate, vegetation and other factors to

(9) Agriculture and Agri-Food Canada website, taken from a page available at the following address: http://www.agr.ca/policy/environment/eb/public_html/ebe/climate.html, updated 29 July 1999.

(10) *Ibid.*

(11) Agriculture and Agri-Food Canada, 1998.

(12) R.L. Desjardins and R. Riznek, "Agricultural Greenhouse Gas Budget," *Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project*, Agriculture and Agri-Food Canada, 2000.

(13) *Ibid.*

calculate an estimate of changes in carbon resulting from farming practices. However, a great deal of research remains to be done, particularly on practices that sequester carbon in certain types of soil.

E. The Kyoto Protocol

Unlike reforestation, carbon sequestration in agricultural soil was not included in the original Kyoto Protocol; in other words, soils are not officially recognized as carbon sinks, and carbon stored in soil cannot be factored into a country's emissions budget.

To rectify the situation, Canada pushed to have carbon sinks included in the Protocol: this was done in agreement with many Canadian stakeholders, including the Agriculture and Agri-Food Table on Climate Change,(14) which recommended in January 2000 that the federal government continue its efforts to have agricultural soils recognized as carbon sinks in the Protocol.(15) The initiatives taken by the government and the industry to implement measures aimed at reducing the effect of greenhouse gases were designed with that objective in mind.

Negotiations on application of the Kyoto Protocol took place in The Hague in November 2000. One of the goals was to reach an agreement on the definition of "carbon sink" and the way sinks would be factored into emissions budgets. The failure of those negotiations did not necessarily end the hopes of seeing agricultural soils included in the Protocol, but rather highlighted the need to overcome obstacles, in particular the need for an economically and technically reliable and efficient method of determining the quantities of CO_2 removed from the atmosphere and stored in soil. The scientific uncertainty over how to quantify that sequestered CO_2 and the temporary nature of agricultural soils as carbon sinks were the main arguments used by those opposed to the inclusion of soils in the Protocol.

FOSTERING THE CREATION OF SINKS

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(14) The Agriculture and Agri-Food Table on Climate Change was created to develop a strategy that would allow Canada to reach its goal under the Kyoto Protocol. The group includes representatives of the provinces, the agriculture industry and universities.

(15) Agriculture and Agri-Food Table on Climate Change, *Reducing Greenhouse Gas Emissions from Canadian Agriculture*, Report on Options, January 2000.

Among the various measures aimed at reducing greenhouse gas emissions are those which use the market by putting a price on carbon (for example, a tax or a tradeable permit system) and those which use the power of regulations to limit certain practices (for example, energy efficiency standards for motor vehicles). These measures do not necessarily foster the creation of carbon sinks. This section therefore focuses on the establishment of a carbon market and the appeal that this approach might hold for farmers. It goes on to briefly describe other solutions and their impact on the adoption of practices that promote carbon sequestration.

A. A Market for Carbon

Of all the measures referred to above, "carbon credit trading" is the one that has undergone the most study in Canada[16] and seems to be best able to encourage farmers to adopt practices that promote carbon sequestration and thus the creation of carbon sinks.

The Kyoto Protocol allows the development of emission trading mechanisms as a way of reducing the emission of greenhouse gases into the atmosphere. The first step in implementing an emission trading system is to set a limit on each country's greenhouse gas emissions; each country then distributes its allocation among the various sources of emissions. Finally, the trading system would allow one source to increase the amount of greenhouse gas it emits by trading with another source that was able to reduce its emissions to a level below its allocation.

Carbon sequestration activities such as carbon sinks could perhaps be incorporated into emission trading systems: this would create a "carbon credit" for each additional equivalent unit of CO_2 in the soil. These credits could then be sold to sources of greenhouse gas in order to permit their emissions. Credit trading would give farmers a bonus for adopting methods that promote soil carbon retention.

It should be noted that forestation and reforestation are considered carbon sinks under the Kyoto Protocol. In addition to creating a soil sink by sequestering carbon in soil, the

(16) Robert Hornung, Pembina Institute, Presentation at a Library of Parliament workshop on climate change, 29 September 2000.

conversion of marginal farmland to forest would also be a forest sink that would make it possible to obtain additional carbon credits.

If agricultural soils are recognized as carbon sinks in the Kyoto Protocol, terms and conditions for a carbon credit trading system will have to be established. A number of questions will have to be clarified before a carbon credit trading system is put in place, including:

- Would the system be voluntary or mandatory?
- Would credits be allocated for what a farmer actually sequesters or for the sequestration potential of the soil?
- Who would hold the carbon credits: the owner of the land or the farmer?

B. Does a "Carbon Market" Hold Any Appeal for Farmers?

The following paragraphs discuss the potential impact of a carbon credit trading system on farmers.

Currently, it is difficult to predict what value carbon will have for farmers. There is still no way to determine the quantity of carbon that will be sequestered, the price paid for a unit of carbon, and the terms of payment.(17)

It is a fairly safe bet that the quantity of carbon sequestered on an individual farm will be too small to be tradeable. However, considering that Canada has 45.5 million hectares of farmland, there is considerable potential for tradeable credits. Without question, a method of pooling carbon credits in order to obtain a significant tradeable volume will have to be devised.(18)

The establishment of a significant market also entails a trading mechanism that would allow farmers to buy credits. Under such a mechanism, farmers interested in expanding an animal breeding operation or taking another initiative that would burn fossil fuels or increase other greenhouse gas emissions would have to pay for credits.(19)

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(17) *Carbon Sequestration and Trading Implications for Canadian Agriculture*, Discussion paper tabled at the workshop entitled *Carbon Sequestration and Trading Implications for Agriculture*, coordinated by the Soil Conservation Council of Canada in December 1998.

(18) *Ibid.*

(19) Daynard Terry, "Agriculture and Kyoto – An Update," *Ontario Corn Producer*, Vol. 15, No. 7, August-September 1999, pp. 6-7.

C. Other Approaches

Other tools are available for encouraging farmers to use methods that promote soil carbon sequestration. For example, a conservation easement is a legal agreement whereby a landowner voluntarily restricts or limits the type and scope of development that he or she can carry out on the land in return for financial compensation. This system is used in the United States to conserve wildlife habitat (*U.S. Conservation Reserve Program*) and could be adapted to greenhouse gases, mainly by encouraging farmers to take marginal farmland out of production and convert it to perennial grasses or forest. Such a system seems at first glance to be incompatible with a carbon credit trading system – one party would be paid twice for the same service. Moreover, there is the problem of the criteria on which financial compensation would be based. In this type of program, loss of productivity or shortfall resulting from use of the practices in question generally serve as the basis for compensation. However, practices that sequester carbon do not necessarily lead to a drop in production or a shortfall.

Among the other approaches aimed at reducing greenhouse gas emissions, the imposition of a "carbon tax" is one solution that has the support of many environmental groups. It is difficult at this time to estimate the possible impact of a fossil fuel tax on the adoption of practices that foster carbon sequestration, although some of those practices reduce energy consumption – direct drilling, for example, which requires less machinery. According to a document produced in 1998 for the Agriculture and Agri-Food Table on Climate Change, the farming process is too complex to assume that imposing a tax will bring about an increase in practices that sequester carbon and, more generally, a decrease in agricultural CO_2 emissions.[20] That approach has not subsequently been studied a great deal in Canada.[21]

Regulatory measures that would make it mandatory to use practices that sequester carbon in soil could be viewed as a violation of property rights. Nor are regulations a method traditionally used in Canada to set parameters for farming: "good farming practices" guides are voluntary and are rarely set out in regulations. Management of animal waste is an exception, because most provinces have regulations governing the storage and spreading of manure.

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(20) Don Buckingham and Cynthia Kallio Edwards, "Non-economic policy instruments aimed at reducing agricultural greenhouse gas emissions," Presentation at the Montreal workshop of the Agriculture and Agri-Food Table on Climate Change, 17 November 1998.

(21) Robert Hornung, Pembina Institute, Presentation at a Library of Parliament workshop on climate change, 29 September 2000.

CONCLUSION

Soil carbon sequestration is one way of reducing agricultural greenhouse gas emissions, and the creation of a market for reducing carbon emissions would enable farmers to benefit economically from the process.

However, Canada will not be able to include soil carbon sequestration in the measures it takes to reduce greenhouse gas emissions if the Kyoto Protocol does not recognize agricultural soils as carbon sinks.

Moreover, the process does not resolve the entire issue of agricultural greenhouse gas emissions. The gains achieved through carbon sequestration must not be accompanied by an increase in greenhouse gas or CO_2 emissions from sources other than soil, particularly if those emissions are part of the carbon credit trading system. The benefit resulting from soil carbon sequestration would be severely reduced or perhaps even wiped out altogether. Carbon sinks are not a permanent solution because soil carbon reserves reach a new balance after a number of years and the practices needed to prevent the CO_2 from being re-released have to be maintained.

Other practices can be used to reduce agricultural greenhouse gas emissions: for example, replacing a portion of mineral nitrogen fertilizer with legume cover in winter reduces the indirect CO_2 emissions attributable to fertilizer production.(22) Farmers will therefore have to include soil sinks in a broader strategy aimed at reducing their greenhouse gas emissions.

(22) G.P. Robertson *et al.*, "Greenhouse Gases in Intensive Agriculture: Contributions of Individual Gases to the Radiative Forcing of the Atmosphere," *Science Magazine*, Vol. 289, No. 5486, 15 September 2000, pp. 1922-1925.