Agriculture and the Greenhouse Gases

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Summary

The atmosphere is changing, notably from emissions of greenhouse gases - CO_2, CH_4, and N_2O - released from human activity worldwide. With rising concentrations of these gases come fears of abruptly-altered climate, prompting demands to reduce emissions. Canadian farmers are closely linked to this effort; not only can they aim to reduce their own emissions, but they can sometimes also remove CO_2 from air by building soil carbon. Far-sighted responses to this issue may be best envisioned through conversation among farmers, scientists, policymakers, and public citizens. That way, the challenges ahead are illuminated by collective wisdom, and climate change may become, not just an ominous problem, but also an opportunity.

Introduction

The air about us is changing. Within our lifetimes, its concentration of greenhouse gases has risen sharply. And if this trend continues, say many scientists, our climates may be abruptly altered, creating a cascade of global consequences, some unpleasant. As a result, climate change has vaulted to the forefront of Canadian thought. Dire predictions abound in news reports, animated debates swirl in newspapers and local coffee shops, and increasingly we hear pleas to reduce our emissions of greenhouse gases.

What is the place of farms in this new urgency? What emissions do they produce, and what can farmers do to reduce those emissions? These are the questions I pose in this contemplative review. More specifically, I hope to provide a brief overview of emissions from farms, and then to proffer some ways in which we, as members of farming communities, can respond. The underlying aim is not to contribute more data and facts; a blizzard of such findings is already available. Nor is it to propose a way forward; sadly, I do not see the future clearly at all. Rather, I hope merely to invite further conversation so that we, as an agricultural community, can make a far-sighted response together.

The Issue

Before pondering possible responses, we need first to sketch briefly the problem itself. At the core of climate change is the fate of carbon: the conveyor of energy among living things on earth. Occurring in air as CO_2, carbon is invested with solar energy by photosynthesis in plants, trapping it in various tissues. This plant carbon may reside in energized form for a time - in the leaf of a tree for a few months, for example, or in soil organic matter for a thousand years. But eventually it is 'burned' as fuel, back to CO_2, by organisms of all kinds, from microbes to people. And so countless carbon atoms stream endlessly through all living things, delivering energy and then being released to air again, to begin the cycle anew.

No-till farming systems, widely adopted by prairie farmers, provides many benefits to all Canadians. It withdraws atmospheric $C0_2$, reduces erosion, provides habitat for waterfowl, reduces fossil fuel use and helps to conserve moisture.
Photo credit: Guy Lafond

Globally, these movements of carbon are enormous (Figure 1). Each year, about 60 billion tonnes (Pg) of carbon are removed from air by photosynthesis[1]. Much of this is added eventually to soil, becoming organic matter or 'humus'. At the same time, a roughly equivalent amount of carbon (60 billion tonnes) is being 'burned' back to CO_2, mostly by microbes, so that despite the massive flows of carbon, the amount in the air stayed roughly the same from year to year, over many centuries and millennia.

That changed, however, when humans began disturbing the natural flows and stores of carbon. First they cleared land of trees, releasing the carbon they contained; and they plowed grasslands, accelerating the decay of their organic matter to CO_2. More ominously, they began extracting carbon from ancient fossil reserves - coal and petroleum - burning it as fuel, thereby spewing carbon that had lain inert for millions of years back into the air. A century ago, these emissions were small, but with growing populations, and industrialization, the amounts have increased, so that we now emit globally about 7 billion tonnes of fossil carbon into the air each year - more than a tonne per person on earth each year[2,3].

Some of that extra carbon is absorbed by oceans and plants, but only about half. The rest accumulates in the atmosphere, so that every year, the amount of carbon in air increases by about 4 billion tonnes (Figure 1). When expressed as a concentration, this increase per year amounts to about 2 parts per million (ppm). Before the industrial revolution, CO_2 content was about 280 ppm; now it has surpassed 380, and it is sure to rise further, perhaps reaching 500 ppm or more before century's end[2].

Why is this a worry? Carbon dioxide is benign; indeed it is needed for life, and plants may actually grow faster with higher CO_2 - so why the anxiety? Well,

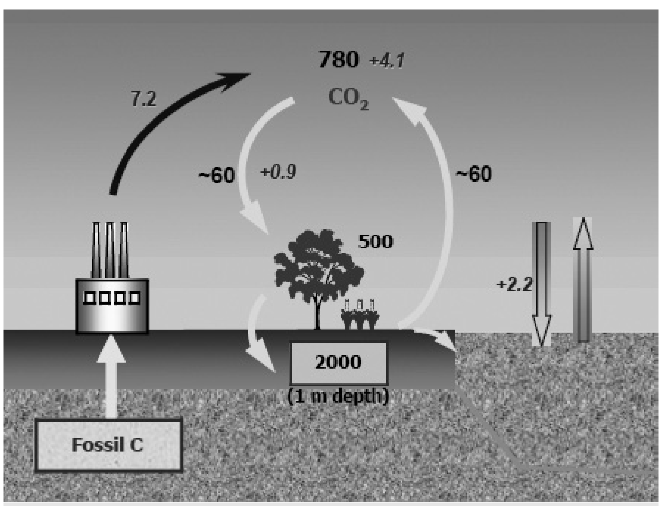

Figure 1. A simplified view of the global carbon cycle in 2000 - 2005. The atmosphere contains about 780 Pg (billion tonnes) of carbon as CO_2. Vegetation holds about 500 Pg carbon, mostly in trees, and soils hold roughly 2000 Pg carbon in organic matter. Every year, plants remove and store about 60 Pg carbon; at the same time, a roughly equivalent amount is released back into the air, mostly by microbial decay of organic materials on or in the soil. The oceans, too, exchange large amounts of carbon with the air each year. These exchanges, and feedbacks among them, have held atmospheric CO_2 concentrations reasonably constant for thousands of years. Recently, however, humans have been injecting more and more CO_2 into the air by burning of fossil fuel - about 7.2 Pg carbon per year. Earth's vegetation removes some of this excess (about 0.9 Pg) and the oceans absorb even more (about 2.2 Pg), but that still leaves about 4.1 Pg in the air, which amounts to an increase in concentration of about 2 parts per million (ppm) each year. (sources: references 2, 4, and references cited in 4).

CO_2, like other 'greenhouse gases', absorbs energy radiating from the earth's surface, keeping a layer of warmth in which life on this planet thrives. This 'greenhouse effect' is a good thing - without it, our planet would be barren and cold - but if CO_2 concentration rises too fast and too high, the warming may be excessive, disrupting the climate. And if the climate changes, especially abruptly, that may induce further unsettling effects: sea level rise, more severe weather events, human health effects, disrupted wildlife habitats, and water shortages, among others[5].

Carbon dioxide is the most worrisome greenhouse gas, but not the only one. Methane (CH_4) is another - a greenhouse gas about 25 times as potent as CO_2. It is released to air when plant material decomposes without enough oxygen to produce CO_2, notably in the rumen of livestock and in flooded rice fields. Although now stabilizing somewhat, concentrations of methane in the air have more than doubled since the Industrial Revolution, and agriculture is a dominant source of this gas (Table 1).

Another greenhouse gas is nitrous oxide (N_2O). Though present in the atmosphere in only trace amounts, it is a highly potent greenhouse gas - about 300 times as powerful as CO_2 - and its concentration too has increased by 18% since the Industrial Revolution. And, like methane, N_2O from human activity comes largely from farms, specifically from the nitrogen added to farmlands to maintain soil productivity. This raises a worrisome question: if more and more food is needed to feed growing human populations, and more and more nitrogen needs to be added to soil to replace that removed in yields, can we expect to reduce emissions of N_2O?

The concentrations of greenhouse gases in the air are increasing, with foreboding consequences to climate, environmental health, and human society. And agriculture is deeply embedded in these changes, both as a source of greenhouse gases, and as a vulnerable recipient of their potential consequences.

Canadian agriculture: its role in greenhouse gas emissions

In Canada, agriculture accounts for about 10% of total emissions[7]. In 2005, for example, total emissions from all human-derived sources in Canada were 747 million tonnes of CO_2 equivalent (CO_2e).[6] Of this Canadian total, agriculture emitted an estimated 57 million

Table 1: *The past and present concentrations of three main greenhouse gases.*

Greenhouse gas	Pre-industrial concentration	Concentration in 2005	Global warming potential#	Main human-derived sources
CO_2	280 ppm*	379 ppm	1	Energy use; deforestation
CH_4	0. 72 ppm	1.77 ppm	25	Agriculture; energy use
N_2O	0.27 ppm	0.32 ppm	298	Agriculture

source: reference 2

* ppm = parts per million by volume. For example, 280 ppm means that 1 million liters of air holds 280 liters of CO_2.

\# Global warming potential is the relative warming effect of the gas, compared to CO_2, when considered over a 100-year period. Thus, one kg of CH_4 has 25 times the warming effect of 1 kg CO_2.

tonnes CO_2e, roughly half as CH_4 and half as N_2O[8], of which the thee Prairie Provinces contribute roughly 60%. (In addition, farms also release small amounts of CO_2 from energy use, though that is usually counted in under energy use).[7]

But farmlands affect atmospheric greenhouse gases also in another way: through losses or gains of carbon in soils. Farmlands hold vast stores of carbon in their organic matter - as much as 150 tonnes per ha or more in the surface metre, compared to 15 tonnes carbon in the air above that ha. And the carbon in soil is linked to carbon in air: new soil carbon comes from plant carbon recently removed from air by photosynthesis, and the decay of soil organic matter releases CO_2 back into air. Consequently, if farmlands lose carbon, CO_2 is released to the air; if they gain carbon, CO_2 is removed from the air.

Historically, many agricultural soils lost large amounts of carbon, typically up to 30% or more of the carbon in surface layers, much of it soon after initial cultivation. But improved practices, such as reduced tillage and better cropping sequences, can reverse that trend[7]. Thus, in 2005, croplands in Canada removed roughly 10 million tonnes of CO_2 from the atmosphere each year[9]. At the same time, however, forest lands recently converted to croplands were losing roughly an equivalent amount so that, as a whole, Canadian farmlands are now neither losing nor gaining appreciable carbon.

And there is yet another way that farmlands are tied to greenhouse gas emissions, albeit indirectly: by producing crops used to make biofuels. These fuels - ethanol, biodiesel, and others - are increasingly seen as alternatives to fossil fuel. They still release CO_2 when combusted, but from recently photosynthesized plant material, so the CO_2 is re-cycled atmospheric carbon. To date, biofuels represent only a tiny fraction of Canada's fuel use, but many foresee their role expanding.

Canada's farmers, then, are immersed in the unfolding aims to reduce greenhouse gas emissions. How they manage their lands and livestock affects Canada's emissions - negatively or positively - and Canada's policies to reduce emissions, in turn, affect how farmers manage their lands What then should be the response of the farming community to impending climate change?

Our response

Agriculture's response is best considered collectively, including views of farmers, decision-makers, scientists, and other members of the farming community. Merely to stimulate further conversation among us, I propose seven possible responses that farmers, and those working alongside, might want to consider.

1. Recognize the challenges - together

Reducing greenhouse gases is increasingly seen as an urgent objective, so that a wide array of practices and solutions has been proposed to reduce greenhouse gases from farms. Most have merit, but they are not equally effective everywhere. For example, many studies have shown that improved land practices, such as no-till, avoiding summerfallow, planting perennial crops, and re-establishing grasslands on marginal lands can increase soil carbon reserves, thereby removing CO_2 from air. But the amount of carbon gain will vary widely, depending on soil type, farming history, other practices, and climate. Sometimes, a practice is effective in one place, but ineffective in another. For example, no-till often increases soil carbon on the prairies, but may have little benefit in the moister soils of central and eastern Canada[10]. Finding the best practices therefore depends on intimate understanding of the farmlands in question. Such wisdom is perhaps best acquired by the careful confluence of science and experience, gained from scientists conversing with producers.

2. Admit uncertainties

Measuring emissions or reductions in emissions is not always easy. For example, nitrous oxide tends to erupt from soils in bursts and puffs, often at times such as snow-melt when measuring is not convenient[11]. Similarly, changes in soil carbon, because they are so gradual, often cannot be measured until years have elapsed after adopting a new practice[12]. As a result, emissions and potential reductions are often estimated using 'models' - mathematical equations based on previous measurements. These models are improving, as research continues, but their outputs are still best seen as approximate and awaiting refinement.

Such uncertainties should not deter us from seeking to reduce emissions; indeed they may help tune our responses, by enforcing humility and by avoiding incautious adoption of practices that might deliver less than promised by eager advocates.

3. Look for opportunities that reduce whole-farm emissions

Farms are remarkably complex ecosystems, including many facets - different crops, livestock, machinery, and human inventiveness - all interacting. Thus, the effects of changing any single practice cascade throughout the system. A new ration to reduce methane emissions from beef may affect nitrous oxide emissions from fertilizer applied to grow the crop; growing more forages to sequester carbon may alter methane emissions when that hay is fed to cattle; new methods to reduce emissions during storage of manure may affect emissions when the manure is later applied to the land. All these feedbacks need to be considered if we are to develop practices that reduce emissions from the farm as a whole, rather than merely from one part of the farm. This system-wide approach adds complexity, but it also presents exciting opportunity for interplay of insights among various facets of farms, notably between livestock and crops, sometimes treated separately.

Carbon Sequestration: The Removal of Atmospheric Carbon Dioxide

Managing prairie soils to reduce erosion benefits the farm in other ways as well. Increases in soil organic matter content also increase atmospheric CO_2 sequestration. Principal conservation strategies, which sequester carbon, include converting marginal lands to compatible land use systems, restoring degraded soils, and adopting Beneficial Management Practices (BMPs). Removing marginal land from annual crop production and replacing it with livestock grazing and/or wildlife habitat, will lead to more biomass production and better net increases in soil organic carbon content.

Canadian cropland can sequester about 22 million tonnes of atmospheric CO_2 per year by using current BMPs. Canadian grazing land can sequester 3 million tonnes of atmospheric CO_2 annually by controlled grazing, fire management, use of fertilizers, improved cultivars, and wetland restoration.

Carbon Trading

Properly managed prairie agricultural soils are highly efficient "carbon sinks". These sinks will be a critical component of Canada's ability to meet greenhouse gas emission targets established by the Kyoto Protocol.

The Government of Canada is proposing a national Offset System that markets stored carbon while Alberta has instituted its own Offset System. Offsets serve as "bridges" for the emitters as they use the carbon in the carbon sinks to offset their higher-than-regulated levels of emissions.

Trading carbon sinks, however, is not without risk. Farmers create carbon sinks by storing carbon in their soils through a variety of methods including no-till farming and seeding forages on marginal lands. But the process is reversed if, for some reason - perhaps drought or disease, the land must be tilled. With every tillage operation, some of the carbon stored, is lost. If the stored carbon has been "traded", then the farmer faces certain liabilities.

Several policies have been proposed in order to address the liability concerns. Policy-makers must recognize in order for an Offset System to be successful, the widespread cooperation of thousands of individual farmers is a requirement. Their cooperation will depend upon how well the policies limit risk to the farmers.

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4. Consider all ecosystem services

Reducing greenhouse gas emissions has become an urgent aim, and the objective is certainly a worthy one. But Canadian farms serve many functions: they provide food for millions, generate livelihood for countless families, provide silent services like filtering air and water of impurities, offer habitat for wildlife, and, not least, give respite for mind and spirit through aesthetic appeal[13]. These other services too are essential - at least as important as reducing greenhouse gases.

Fortunately, many practices that reduce emissions also promote other benefits. For example, adopting no-till may not only withdraw atmospheric CO_2, but also reduce erosion, provide habitat for waterfowl, reduce dependence on fossil fuel, and help conserve moisture, making yields less vulnerable to drought. Similarly, using manure more efficiently as nutrient source may not only reduce N_2O emissions, but also lower fertilizer use, thereby reducing costs and energy use in making the fertilizer.

But sometimes a practice that reduces greenhouse gas emissions exacts a cost on other ecosystem services. For example, growing crops for bio-fuels may reduce CO_2 emissions from fossil fuels, but this benefit may come at the expense of growing food. Similar trade-offs occur also in other potential options. For example, are we willing to recommend reduced fertilizer rates that might suppress greenhouse gas emissions, but at the expense of crop yields, or reduced long-term soil quality? Or, conversely, are we willing to adopt a practice that increases emissions by 10% if they bolster another ecosystem service (e.g., food production) by 30%?

These few examples illustrate that reducing greenhouse gases cannot be seen as an isolated goal; it should be viewed as one of many aims contemplated together as farmers and policymakers plan the best way to use our farmlands for us and for the generations to come. A proposed practice that reduces emissions but does not also favor other services will likely never be effective for it won't be widely adopted - nor should it be.

5. Use GHG's as indicators

One way to consider GHG mitigation, alongside other ecosystems services, is to use emissions as an indicator of efficiency[14]. Usually, when a farm emits excess greenhouse gases, that is a sign of inefficient use of energy, nutrients, or resources. High rates of N_2O emission from soil may indicate inefficient use of nitrogen; high CH_4 emission from cattle may signify less-than-optimal use of feeds; high CO_2 emission from soil carbon loss denotes inefficient use of solar energy stored as organic matter; high CO_2 emission from diesel fuel indicates inefficient use of fossil energy. Researchers, then, look for high emissions and find ways of suppressing them; producers ask, in turn: can these new practices make my farm more efficient? From this perspective, estimating greenhouse gases is seen not as an end in itself, but as a way to highlight opportunities for improved farming. And the benefits of adopting practices that reduce emissions may extend far beyond merely mitigating climate change.

6. Prepare for change

The world is facing tumultuous change in the next few decades[15]. That change is not limited to climates; indeed, other changes may be more profound than those to climate[16]. By the year 2050, say many prophets, global demands for food may nearly double, competition for dwindling water resources will intensify, lands for habitat of wildlife may shrink further, and energy will be ever more expensive[17-21]. Already the effects of shrinking food reserves are reverberating around the world. And beyond these quite predictable trends are likely others we cannot yet foresee: scientific breakthroughs still beyond our purview, ecological responses our models cannot fathom, instances of human ingenuity (or absence thereof) we cannot imagine. If, as predicted, the climate warms or precipitation patterns are altered, that just adds another dimension of change.

Canadian farmers are not immune from these changes; indeed, they may be among those most affected. Confronting all the changes will require resilience and a capacity to see beyond the immediate problems to the solutions lying decades ahead. Fortunately, past experience has demonstrated, time and again, that Canadian farmers are adept at managing change, not only buffeting the stresses that come, but also extracting opportunity from them.

7. Remind urban neighbours of the value of farmlands

The greenhouse gases wafting about in the air do not honor the fences of farms, or the boundaries between cities and farmlands, or the artificial lines drawn on international maps. The N_2O or CH_4 molecules released from farms spread across land and sea, exerting warming effects globally; and the CO_2 withdrawn from air by good farming practices likewise benefit all society. The greenhouse gases therefore illustrate, perhaps in a way unprecedented, the interdependence of all communities. They demonstrate, even, our interdependence with generations far into the future, for the effects of today's emissions or withdrawals of greenhouse gases linger for decades and centuries.

This issue therefore presents a unique forum to remind urban friends of the continuity of all ecosystems. It provides a podium from which to remind them (and ourselves) that what we do on the land has enduring influence on so many facets of their lives; and that, in return, what our city neighbors do - what they eat, what they drive, how they think - has lasting influence on the look of the countryside. Our challenge now is to communicate that story effectively: conveying the value of farmlands and the urgency of preserving their health, not only for the sake of those who live there, but for all of society, now and into the future.

Concluding thought

Impending climate change is often seen as an ominous problem - and it is all of that. If current predictions come true, then future generations may see unpleasant consequences unless we soon find ways of curtailing greenhouse gas emissions. Impending climate change is a problem, yes - but also it is an opportunity. It helps us look at our farmlands - these ecosystems so essential to all of us - from a new perspective. It guides us toward long-term solutions, it helps us aim for higher efficiency and more careful resource use, and it reminds us of the value of these farmlands and the urgency of preserving them for those who will follow. Our collective challenge, then, is to respond to impending climate change with ingenuity, inventiveness, and far-sightedness, so that a generation or two from now, those who look back on our work see it as a turning point toward optimism.

Notes and References

1. Scientists call this annual amount of carbon stored in plant material 'Net Primary Productivity' (NPP)

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