CHAPTER 49

Reducing Greenhouse Gases from Ruminants on Perennial Pastures

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Steers on native pasture with condensed tannin legume.

What are greenhouse gases?

Greenhouse gases (GHGs) are atmospheric gases that absorb and release radiation within our atmosphere. While GHGs allow the sun's energy to enter the atmosphere, they trap infrared radiation that would otherwise radiate into space. This 'greenhouse effect' is linked to global warming and climate change. Greenhouse gas emissions occur naturally through biogenic processes such as the decomposition of organic biological materials and through anthropogenic sources. Agricultural contributions to total GHG emissions in Canada and the U.S. are relatively small, accounting for about 8.1% and 6.3% respectively (EPA 2011; Environment Canada 2011). The main agricultural GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Carbon dioxide comes from fossil fuel combustion in farm machinery and losses of soil organic matter. Methane emissions come from stored livestock manure and from ruminant animals during the normal digestive process of enteric fermentation. Nitrous oxide comes from applications of N fertilizers and manure. In Canada, CH_4 and N_2O emissions account for about 39% and 61% of total agricultural GHG emissions (Environment Canada 2011). In the U.S., enteric fermentation is the second largest anthropogenic source of CH_4 emissions while manure and fertilizer application are the largest source of anthropogenic N_2O emissions (69% of total agriculture emissions).

Win-win opportunities

Agriculture is a significant contributor to Canada's GHG emissions, and both CH_4 and N_2O are long-lived GHGs with long-term influence on our environment. As a result, the Government of Canada, Provincial Governments and the Industry are looking at ways to reduce emissions of these potent GHGs. The loss of CH_4 and N_2O represent production inefficiencies and loss of energy, therefore reducing these losses will improve the efficiency of forage and livestock production. This should be seen as a potential win-win opportunity for forage and livestock producers and not a threat to the agricultural industry. Properly managed grazing livestock and perennial grasslands are more productive, more profitable, and provide the best opportunities to reduce GHG emissions and improve our environment and sustainability.

Agricultural sources of methane emissions

Figure 1 shows the various CH_4 emission sources from animal production in Canada in 2009.

Enteric fermentation: Methane is produced during the normal digestive process of enteric fermentation by herbivores. Microorganisms (e.g., methanogenic bacteria) break down carbohydrates and proteins into simple molecules for absorption through the gastro-intestinal tract and CH_4 is produced as a by-product. This process results in an accumulation of CH_4 in the rumen that is emitted by eructation and exhalation. Some CH_4 is released later in the digestive process by flatulation, but this amount is very small (< 2% of total emissions) (McGinn et al. 2007). On average the daily CH_4 emission from a grazing yearling or a mature cow can range from about 175–300 g/day and emission rates will vary depending upon dietary factors such as: type of forage, level of intake and production, grazing systems, environment etc. Cattle typically lose 6% of their ingested energy from CH_4 being eructated. Since CH_4 represents a loss of carbon from the rumen and thus an unproductive use of dietary energy, animal researchers have been looking for ways to suppress its production. The most promising CH_4 mitigating strategies involve improving the productivity and efficiency of livestock production.

Methane emission from manure management: Cattle manure in Canada can be stored over several months with about 14% of cattle operations storing liquid slurry, 69% storing solids and 24% having no storage by keeping their animals on pasture year-round or spreading manure daily (Kebreab et al. 2006). The CH_4 production potential of manure depends on its composition, which is dependent upon the composition and digestibility of the diet. Methane production during decomposition in the absence of oxygen is affected by the climate, solid content of the manure, and manure handling practices. Generally, liquid and solid manure storage systems have the most potential for CH_4 emission. Methane emissions from cattle excreta can be quite variable but averages 0.96 and 0.03 g CH_4 /d /cow for confined and grazing cattle (Yamulki et al. 1999). In contrast, when dung is decomposed in the presence of oxygen there is little to no CH_4 produced but CO_2 is released. Optimal conditions for CH_4 production requires anaerobic (no oxygen) conditions, high level of nutrients for bacterial growth, neutral pH (close to 7.0), warm temperatures and moisture.

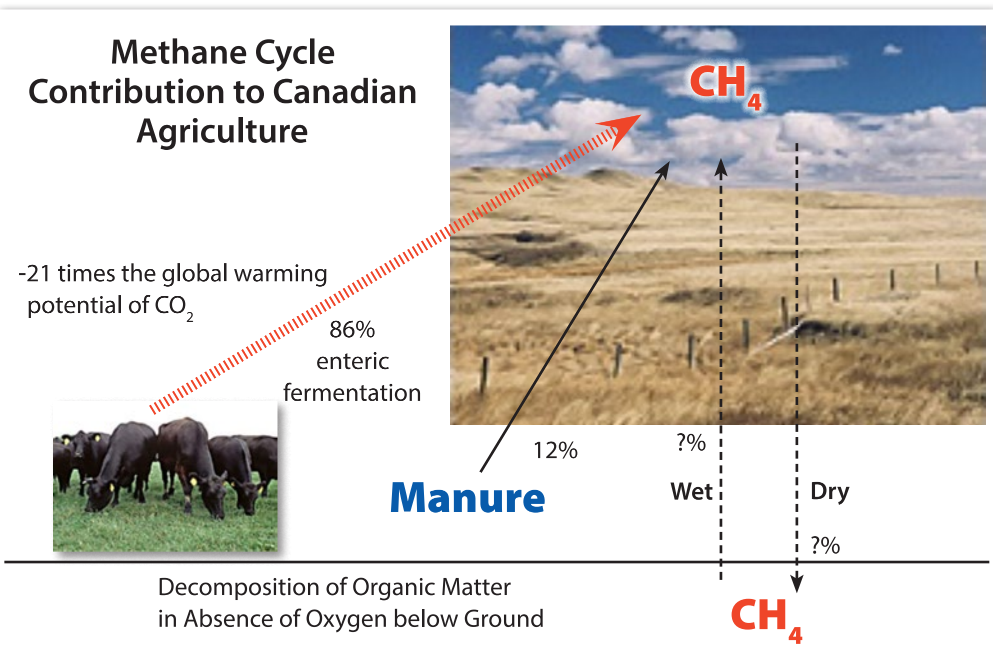

Figure 1. Methane cycle contribution to Canadian agriculture in 2009.

Agricultural sources of nitrous oxide emissions

Figure 2 shows the various N_2O sources from cattle production (manure management systems, manure applied on pasture and as fertilizer) and other cropping sources.

Nitrous oxide emissions from manure management: Production of N_2O occurs during storage and treatment of animal waste during nitrification of ammonia and denitrification of nitrate contained in the manure and urine. During nitrification, bacteria oxidize N through a two-step aerobic process. Two groups of nitrifying bacteria are responsible: those that oxidize ammonium (NH_4^+) to nitrite (NO_2^-) and those that oxidize nitrite to nitrate (NO_3^-). Nitrous oxide is produced as a by-product of ammonium oxidation during the multi-step process (EPA 2010; Environment Canada 2011). In denitrification, bacteria reduce oxidized inorganic forms of N. This process may form N_2O as an intermediate by-product, or it may utilize N_2O. Thus denitrification can be either a source or a sink for N_2O depending upon environmental conditions such as oxygen and N levels, pH, and temperature of the manure (EPA 2010; Environment Canada 2011). In cattle drylots, manure is stored and handled as a solid, which is the manure management system that emits the most N_2O since aeration can increase N_2O emissions. Several management strategies are available to reduce N_2O fluxes from manure storage, including composting, diet manipulation, and bedding additives in manure.

Nitrous oxide emissions from agricultural soils: Nitrous oxide emissions from agricultural soils consist of direct and indirect emissions, as well as emissions from animal manure deposited on pasture, rangelands and paddocks. Manure applied as fertilizer to agricultural soils is both a direct and indirect N_2O emission source. Some of the applied N may be transported off-site as volatilized ammonia and subsequently redeposited where it stimulates N_2O emissions. Production of N_2O in soils is generally proportional to N input and influenced by soil moisture and type, temperature, aeration status, organic carbon availability and other factors. Dung and urine deposited on the pasture can contribute 0.02 kg N_2O–N /kg N (2%) adding up to 10–12% of the N_2O emissions associated with agricultural soils (about 3 Mt CO_2 eq in 2009) (Environment Canada 2011). Other potential minor sources of N_2O emissions on pasture and rangelands may come from biological N fixation by legume-rhizobium and the burning of grasslands. However, researchers have found no evidence that measurable amounts of N_2O are produced during the N fixation process (Rochette and Janzen 2005) and little grassland is burned due mainly to environmental concerns.

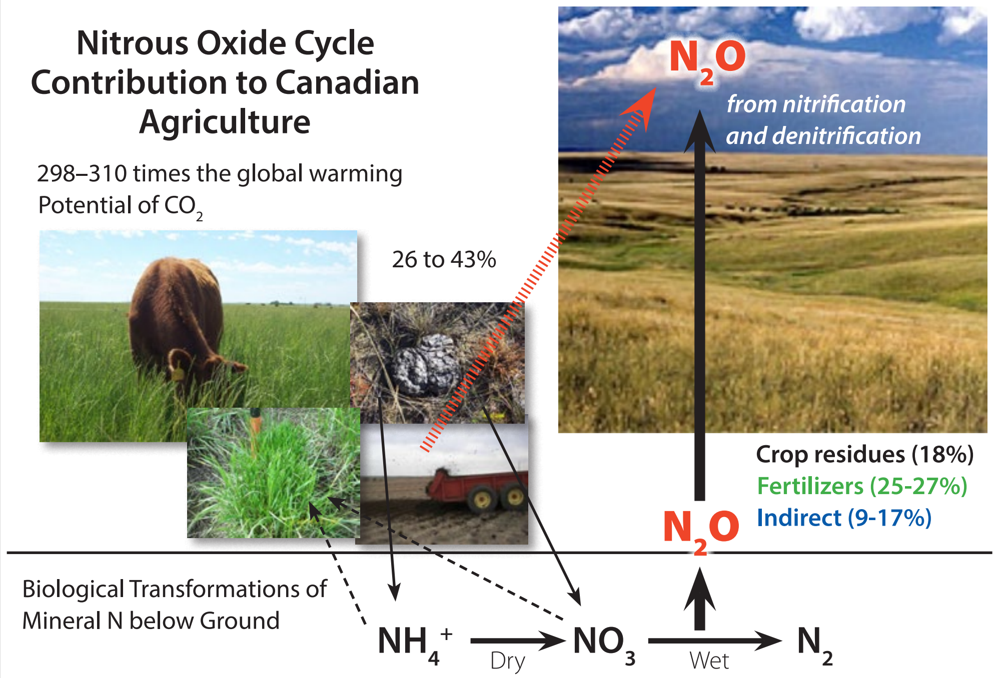

Figure 2. Nitrous Oxide Cycle contribution to Canadian agriculture in 2009.

Improved carbon sequestration through grazing

Improved forage and grassland production and better grazing management can result in soil carbon sequestration. This refers to the transfer of atmospheric CO_2 into the soil C pool through conversion of plant residue into stable humus (Lai 2006). Increasing soil C improves crop productivity, restores degraded soils, and improves quality of surface water by reducing erosion and sedimentation. Rates of soil carbon sequestration are highly variable and depend on conditions and management; conversion of cropland to perennial forage, addition of legumes or N inputs, and managing grazing to restore degraded grasslands can sequester 100–800 kg C /ha/yr.

Management strategies to reduce CH_4 and N_2O emissions

Forage quality, composition and maturity: Numerous studies have reported that better forage quality has a significant impact on reducing enteric CH_4 emissions, whether in the form of conserved feed or on pasture (Ominski and Wittenberg 2006). Boadi et al. (2002) observed that during the early period of the grazing season steers had 44 and 29% less energy lost as CH_4 compared to steers grazing during the mid and late grazing periods, respectively. While forage quality and availability on pasture is important, chemical composition attributes (ADF, NDF, NFC, CP, etc.) of legumes or grasses explain only 20–50% of the variance in CH_4 emissions, and this relationship is not consistent from sheep to cattle (Waghorn and Woodward 2006). We have found no significant relationships for CH_4 emissions with any forage chemical compositions in a three year study of steers grazing sainfoin and alfalfa plus bromegrass. A possible explanation is provided by a study of cows grazing a monospecific stand of timothy at four maturity stages (Pinares-Patino et al. 2003). The lack of response of CH_4 emissions to maturity and forage chemical composition may be attributed to preferential selection by the cows of more nutritional plant parts. We have also observed unexpectedly good animal performance relative to sward forage chemical composition which we attribute to selective grazing. There is still much to learn about methanogenesis in sheep and cattle with respect to feed quality and grazing.

Beef cattle typically retain only about 10–25% of consumed N, excreting 75–90% as urine and especially dung. However, the proportion of N in urine rises with protein concentration and digestibility of forages. We have evaluated the N_2O emissions from dung and urine applied to a native pasture in different seasons. Nitrous oxide emissions were always low (near control) from dung, and also low from urine applied in summer and fall, while urine applied in late spring had markedly higher N_2O emissions. This suggests potentially high emissions from urine excreted by cattle grazing in spring/early summer, especially since these pastures contain high quality forages. Altering crude protein in pasture herbage is not easy; in western Canada, typical spring/summer grassland contains 8–24% crude protein depending upon the forage species. Often this far exceeds optimal concentrations for ruminants. A potential strategy for lowering the protein content of the diet include: grazing of mixed-species pastures with contrasting growth patterns and N concentrations (e.g., crested wheatgrass and alfalfa; cool and warm season grasses), selecting forage species with a slower rate of protein degradation (e.g. containing condensed tannins), or feeding forages with a higher proportion of non-structural carbohydrates (high-sugar grasses) (Waghorn and Woodward 2006). Avoiding application of N as fertilizer or manure during this period will also lower the potential for emissions of N_2O.

Forage species and pasture management: Emission of CH_4 from the ruminal fermentation of legume and legume +grass forages is generally lower than from grasses. Reduced emissions from legumes can be attributed to a lower proportion of structural carbohydrates and faster rate of passage through the digestive tract, which shifts the fermentation pattern towards higher propionate production. However, a recent study in western Canada (AB, SK and MB) found no consistent differences in CH_4 production between alfalfa and grass pastures but differences were found among forage maturities and pasture species compositions at some locations (Chaves et al. 2006). An earlier study in Manitoba showed 25% less CH_4 emissions from beef cows grazing alfalfa+grass pastures (7.1% of GEI) compared to grass-only pastures (9.5% of GEI) (McCaughey et al. 1997).

In New Zealand, dairy cows grazing the condensed tannin containing forages sulla *(Hedysarum coronarium*) and birdsfoot trefoil (*Lotus corniculatus*) produced 13–25% less CH_4 per kg of (dry) feed intake compared to cows grazing perennial ryegrass (Waghorn and Woodward 2006). We have found it difficult to show a strong (negative) relationship between condensed tannin levels in sainfoin (*Onobrychis viciifolia*) and CH_4 emissions in grazing yearling beef cattle. A possible explanation is that the sainfoin was grazed at full flower (for maximum yield) but should have been grazed at the vegetative and full bud stage when condensed tannin concentrations are higher. It is still unclear how polyphenolics like condensed tannins reduce methanogenesis (Waghorn and Woodward 2006).

It may be uneconomic to graze sainfoin at an early growth stage when yields are low unless there is a strong economic benefit from mitigating CH_4 emissions. Other benefits from feeding condensed tannins include reduced incidence of bloat, lower intestinal worm populations, and the nutritional benefits of by-pass protein (Ominski and Wittenberg 2006).

Grazing management also affects CH_4 emissions. For example, in Manitoba CH_4 production was greater for steers continuously grazing at low stocking rates (1.1 steer /ha; 307 L /d) than at high stocking rates (2.2 steers /ha; 242 L /d) (McCaughey et al. 1997) probably because there was less available forage under high stocking. However, when pastures were rotationally grazed, stocking rates had no effect on CH_4 production. At the low stocking rate, CH_4 production was 9% lower on rotational grazing than continuous grazing.

Pasture crops differ in N uptake from soils. For example, orchardgrass (*Dactylis glomerata*) had higher N use efficiency (NUE) over a range of N input levels and environmental conditions than either smooth bromegrass (*Bromus inermis*) or Kentucky bluegrass (*Poa pratensis*) (Zemenchik and Albrecht 2002; Singer and Moore 2003). Orchardgrass had captured more N because of a longer period of rapid growth. We have found that increasing plant diversity can increase forage yield and ecosystem stability, improves grazing animal performance and reduces GHG emissions. There is also evidence that diversified pasture species that include deep rooted legumes and warm season grasses lower nitrate leaching and N_2O emissions. The caveat is that improved NUE may be associated with lower feed quality, slower cattle growth and potentially higher CH_4 emissions. More research is needed on pasture mixtures.

Manure stored and applied to grassland can contribute both CH_4 and N_2O emissions and sometimes mitigation strategies to reduce one GHG can lead to the increase of another. Farm level practices that could reduce CH_4 production from livestock waste include using solid rather than liquid manure handling, applying manure to land as soon as possible (storing manure sometimes is necessary because the soil is frozen, too wet, and applying manure out of synchrony with crop demands for N will affect N_2O emissions), and minimizing the amount of bedding in manure.

Conclusion

Reduction in CH_4 emissions can be achieved through improved feed and forage quality, animal performance and pasture management. Nitrous oxide emissions are dependent on N inputs from urine and feces and are exacerbated by soil moisture conditions. Better N management of dung and urine excretions and matching ruminant requirements to feed composition will reduce N_2O emissions. Practical solutions for GHG emission reductions require an integrated assessment of all GHG because one GHG mitigating strategy may lead to an increase in another. Both CH_4 and N_2O emissions from grazing livestock are difficult to consistently predict or mitigate due to the number of factors that contribute to the overall emissions such as forage production and quality, complexities of diet selection, grazing management and environment etc. However, there are potential win-win situations in which the land manager can improve efficiency of production and reduce CH_4 and/or N_2O emissions.

References available online at www.farmwest.com

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