

# *The Science of Greenhouse Gas Emissions and Grazing Management Strategies: an Investigative/Awareness Report*

by

Tyrchniewicz Consulting

March 31, 2006

23 Appleby Cove,  
Winnipeg MB R2J 4B6  
Ph: 204-256-5528  
E-mail: [atyrch@mts.net](mailto:atyrch@mts.net)

---

Funding Provided By the...

**Greenhouse Gas Mitigation Program for Canadian Agriculture**

*Initiative sponsored by the Government of Canada, Action Plan 2000 on Climate Change*



Canadian Cattlemen's Association



Soil Conservation Council of Canada



Agriculture et  
Agroalimentaire Canada

Agriculture and  
Agri-Food Canada

Dairy Farmers  
of Canada



Les Producteurs laitiers  
du Canada

## Introduction

Greenhouse gas (GHG) mitigation has become a major topic of discussion at international, national and local levels, with strategies being developed to reduce emissions or enhance biological carbon sequestration. The Kyoto Protocol, an international agreement ratified by Canada, was implemented to reduce global GHG emissions, and Canada agreed to reduce its GHG emissions by 6 percent below its 1990 levels. The possibility of man made releases of GHG's possibly contributing to climate change has been the key driver in the push to reduce greenhouse gas emissions and sequester carbon, with many people, including prominent scientists and world leaders concerned about the potential changes to the environment. This concern about greenhouse gases has resulted in a variety of research projects targeted towards mitigating emissions from all sectors.

Current research in some areas indicates that improving the production process by making it more efficient not only reduces greenhouse gas emissions but improves the economics because there is less waste products. From a business perspective more efficient use of inputs improves the economic situation and happens to result in few greenhouse gas emissions.

Traditional agricultural production techniques are being researched to improve their impacts on GHG emissions and soil stored carbon. Some of these production techniques improve the efficiency of the farm and could be implemented for economic reasons as well as the potential for GHG reductions. Much of this information is still in the research stage, and as such has not been made available to the farmers and ranchers responsible for making decisions at the farm level.

While many of the agricultural GHG reduction options proposed by researchers have little immediate application to cattle production from grazed pastures, a few basic concepts offer potential. Most grazing systems have low inputs and the cattle require little attention, which poses a challenge for reducing GHG emissions. Practical GHG reduction will depend on improvements in animal and dietary management, selection of individual animals having low emissions/unit feed eaten and feed supplements designed to reduce GHG emissions, as well as the ability of the pastures to sequester carbon dioxide from the atmosphere and store the carbon in the plants and soils.

The Canadian Cattlemen's Association recognizes there may be value in making this GHG emissions information available to cattle producers. This project is designed to pull together the

relevant GHG emissions science for the beef cattle industry, in particular, that related to grazing management strategies, and including the impacts on cattle production.

The scope of the research includes:

- scientific knowledge regarding the level and/or reduction of enteric fermentation GHG emissions from beef cattle in grazing situations;
- scientific understanding of potential soil carbon sequestration enhancement under various grazing management strategies, as well as shifts from cropland to grazing land.

Research is currently being conducted to reduce GHG emissions from cattle in grazing situations as well as on the ability of pastures to sequester carbon. A significant challenge exists for people trying to use the research to improve their own operations as the research is in different stages of development. For this project, several research areas will be addressed that could assist ranchers in reducing the GHG emissions from their grazing cattle as well as offer potential to increase profit. Research on GHG emissions from cattle is in various stages of development for conditions in Canada. This paper will highlight these stages and some of the existing knowledge gaps.

## Current GHG Emissions

The greenhouse gases associated with agriculture include carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). These GHGs come from a variety of sources within agriculture and differ in global warming potential. Agricultural emissions accounted for 62 Mt or 8.4% of total 2003 GHG emissions for Canada, with N<sub>2</sub>O accounting for 58% of the emissions and CH<sub>4</sub> for 42% in 2003 (Environment Canada, 2005). CO<sub>2</sub> is a very small amount, usually under 1%. These emissions were produced by enteric fermentation by domestic animals, manure management, fertilizer application, and crop production.

Emissions from agriculture are from main categories:

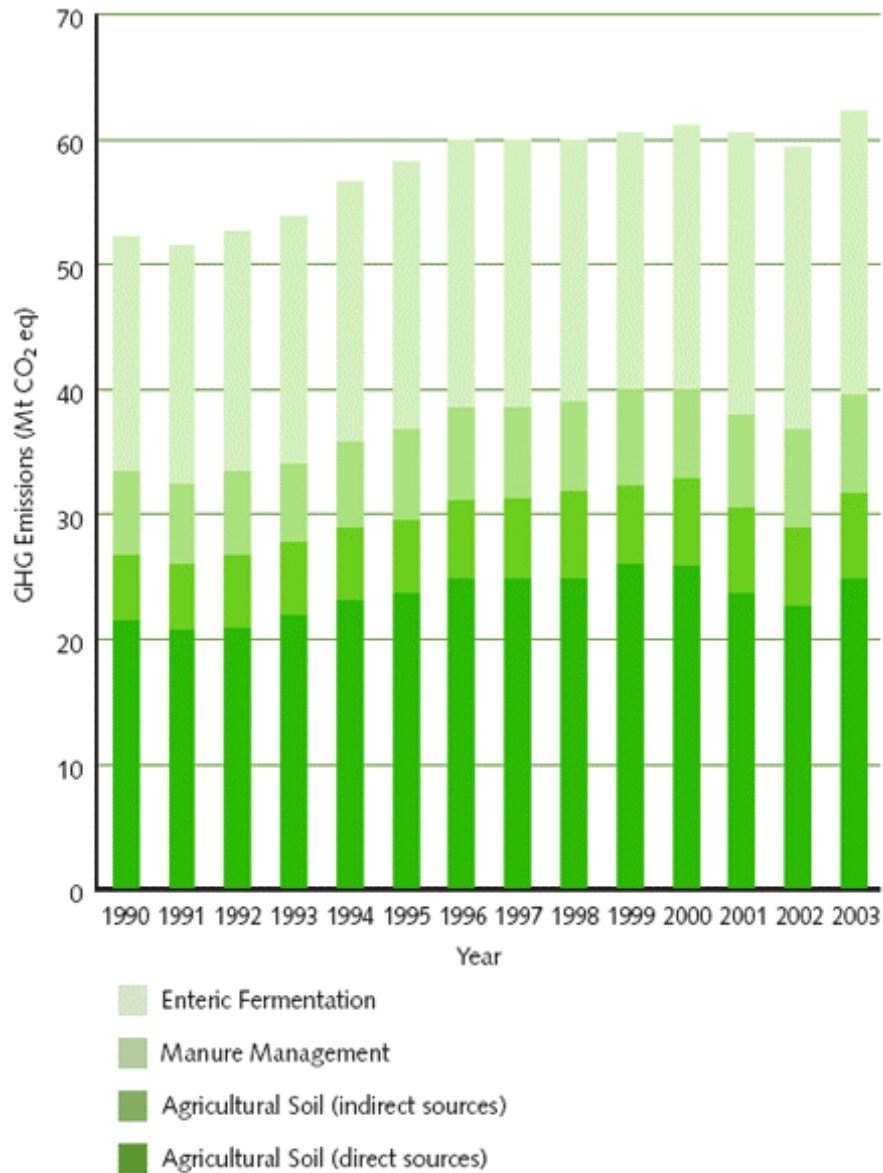
- Livestock-related emissions due to enteric fermentation from domestic animals and manure management, accounting for 49% of total agriculture GHG emissions in 2003.
- Soil management and cropping practices contribute N<sub>2</sub>O emissions due to fertilizer application and legume and non-leguminous crop production, accounting for 51% of total agriculture GHG emissions in 2003.

Canada has over 4.8 million hectares of tame or seeded pasture and over 15.3 million hectares of natural pasture, with a large portion used by beef cattle (Ominski and Wittenberg, 2006).

Through appropriate soil management crop lands, pastures and grasslands have the potential to sequester carbon dioxide from the atmosphere and trap the carbon in plant material and the soil. Canada's pastures are considered a large terrestrial carbon sink (Baron et al., 2006). Older long term pastures tend to sequester carbon dioxide at relatively low rates, however through appropriate management and the conversion of cropland to grassland these rates can be increased.

Figure 1 provides a breakdown of the GHG emissions from the four key agricultural sources for the time period 1990 to 2003.

**FIGURE 1: GHG Emissions from Agricultural Sources, 1990-2003**



Source: Environment Canada 2005.

### Enteric Fermentation

Cattle and other ruminant animals have a unique ability to digest plant materials, such as grass and straw that have high contents of cellulose (Ominski and Wittenberg, 2006). This plant material is digested by the micro-organisms such as bacteria, protozoa and fungi that are found in the rumen. The anaerobic digestion by the micro-organisms, also known as enteric fermentation, results in the production of CH<sub>4</sub> which the animal belches into the atmosphere. Feeds high in fibre, such as straw, result in the production of more methane than forages of low fibre content, such as fresh green grass and alfalfa. The addition of grains, such as corn, barley or wheat, to the diet will reduce CH<sub>4</sub> emissions further. An imbalance in the nutrient content of the feed eaten,

such as a shortfall in the amount of protein or mineral, will also increase the amount of CH<sub>4</sub> produced. For these reasons, cattle fed in a feedlot usually emit less CH<sub>4</sub> than grazing cattle because they consume a substantial amount of grain and the ration is formulated to meet the animal's requirements for nutrients. Environment Canada estimates that enteric fermentation from agricultural livestock represents approximately 1120 kt of methane (CH<sub>4</sub>) or the equivalent of 22,420 kt of carbon dioxide (CO<sub>2</sub>) per year, with beef cattle making up the largest component at 18,600kt of CO<sub>2</sub> (Environment Canada, 2005).

The Intergovernmental Panel on Climate Change (IPCC) has provided a protocol for countries to estimate greenhouse gas emissions. The IPCC uses two approaches for dealing with enteric emissions from livestock, Tier 1 estimates and Tier 2 estimates (BTWG, 2005). Tier 1 estimates use default values for CH<sub>4</sub> emission for different livestock classes. Total emission of CH<sub>4</sub> from that class of animals is then predicted from national inventories of animal numbers in each class. Canada uses Tier 2 estimates, which include more animal classes and calculations based on methane emissions as a proportion of gross energy intake. Table 1 provides the CH<sub>4</sub> emissions from beef cattle categorized by class of animal.

**Table 1 – Enteric Fermentation Emission Factors**

Class	Emission, kg/animal/yr IPCC, Tier 2
Bulls	94
Cows	90
Beef heifers	75
Heifers for slaughter	63
Steers	56
Calves	40

Source: Environment Canada, 2005

The Beef Technical Working Group (BTWG)<sup>1</sup> outlined several research projects that have been undertaken to determine the actual CH<sub>4</sub> emissions from beef cattle. Three of the research projects reviewed by the BTWG were conducted in Canada testing different pasture types, stocking rates and grazing practices. These actual emissions were compared to the Tier 1 and Tier 2 estimates from IPCC. The results of the research projects are shown in Table 2. In all cases, the Tier 1 estimates were considerably lower than the actual emissions, and the Tier 2 estimates tended to underestimate the emissions from most situations. Part of the differences can be accounted for due to the fact the IPCC estimates were based on a combination of feedlot cattle and grazing cattle, while the studies included just grazing cattle. Grazing animals emit more methane on an animal and per-animal-weight basis than feedlot animals.

<sup>1</sup> The BTWG was formed by the National Offset Quantification team, to deliver a quantification protocol to reduce GHG emissions based on beef feeding strategies, such as ration balancing, feed additives and selecting for feed efficiency.

All three of the studies used the same technique for measuring methane emissions, the SF<sub>6</sub> tracer gas method. A capsule with a known amount of SF<sub>6</sub> gas is inserted into the rumen and measuring equipment is placed around the animal's head to determine the concentration ratio of SF<sub>6</sub> to CH<sub>4</sub> emitted from the mouth of the animal. The amount of CH<sub>4</sub> emitted will be directly proportional to the amount of SF<sub>6</sub> emitted. Unfortunately this method does not account for CH<sub>4</sub> produced from flatulence, so values where hind-gut emission of methane was not measured directly were increased by 3% to correct for any methane that would have been emitted through flatulence (BTWG, 2005). A concern with the SF<sub>6</sub> method is that it only measures individual animals, and CH<sub>4</sub> emissions can vary between animals. To measure emissions from larger number of livestock require techniques such as integrated horizontal flux and open-path laser spectrometry. These noninterference techniques tend to provided more realistic emissions associated with livestock activity and grazing/feeding patterns, but may require the SF<sub>6</sub> tracer method for verification (Derner et al., 2005).

**Table 2 - Actual vs Predicted Enteric Emission of Methane (g/head/day) by Beef Cattle fed Pasture.**

	Actual	IPCC, Tier 1	IPCC, Tier 2
<b>Boadi et al., 2002</b>			
Pasture only	230.2	128.8	217.0
Pasture + Barley	245.6	128.8	252.2
Early	190.0	128.8	258.3
Mid	269.9	128.8	198.3
Late	253.9	128.8	246.9
<b>McCaughey et al., 1997</b>			
Graz.man.- Stock. Rate			
Rot graz-Hi SR	195.6	128.8	285.6
Rot graz-LoSR	207.8	128.8	255.8
Cont. graz-HiSR	179.6	128.8	255.3
Cont. graz-LoSR	227.4	128.8	253.8
<b>McCaughey et al. , 1999</b>			
Pasture			
Alfalfa/grass	277.2	197.3	225.1
Grass only	304.8	197.3	192.5
<b>Boadi et al., 2002.</b> Angus beef steers (344.6 kg) grazed a legume/grass pasture and were either unsupplemented or supplemented with barley (2 or 4 kg/hd./day) during the grazing season. Intakes and methane emissions, using the SF <sub>6</sub> method, were sampled on the steers 3 times during the grazing season.			
<b>McCaughey et al., 1997.</b> Crossbred yearling steers (356 kg) grazed 60% alfalfa, 40% grass pastures and managed by rotational or continuous stocking at each of high and low stocking rates (2 x 2 factorial design). Methane emissions measured using the SF <sub>6</sub> method.			
<b>McCaughey et al., 1999.</b> Hereford x Simmental lactating heifers (511.2 kg) grazed alfalfa/meadow brome or meadow brome only pastures. Methane emissions measured using the SF <sub>6</sub> method.			

Source: BTWG, 2005

## **Pasture Sequestration of Carbon Dioxide**

Carbon sequestration is a result of plants taking carbon dioxide from the atmosphere and using it for plant growth. The carbon sequestration potential of soils comes from increasing soil organic matter. The below ground organic carbon storage is usually more than twice above-ground storage. Grasslands contribute huge quantities of soil organic matter over time, mostly in the form of roots, and much of this organic matter can remain in the soil for long periods.

Estimating potential carbon sequestration is more difficult for pastures than for cultivated croplands. Pastures tend to have a wide diversity in plant communities, soils and landscapes. Pasture ecosystem responses are complex, because management practices may induce shifts in plant communities that may, over time, exert secondary effects on the rate of carbon sequestration and the overall carbon storage ability (Schuman et al., 2002). Grazing impacts the ability of pastures to sequester carbon and these impacts differ in different ecosystems. Grazing in the short-grass community resulted in 24 percent more total ecosystem carbon; in contrast, total carbon storage in grazed mid- and tallgrass communities was about 8 percent lower compared to ungrazed sites (Derner et al., 2006).

Moulin et al. (2002) concluded that pasture management has the potential to store carbon in soil particularly when used in combination with fertilizer management on degraded soils or luvisols initially low in soil organic carbon. The researchers also determined that soils high in organic carbon have less potential for carbon sequestration. Currently, long-term carbon sequestration responses to management have not been studied as extensively in rangelands as in cultivated systems, and only a few management scenarios under selected conditions have been documented.

## **GHG Emission Reducing Practices**

A variety of organizations have made recommendations for best management practices that would reduce greenhouse emissions from cattle. The Federal and Provincial governments, conservation and farm organizations as well as a host of other groups have suggestions for management practices that will reduce GHG emissions associated with cattle. Some of the practices are based on quantitative science for the Canadian region, while others do not have the same rigor. To understand which recommendations have value for emission reductions, it is necessary to review the science of greenhouse gas emissions.

In 2003, Alberta Agriculture and Rural Development with the University of Alberta assessed the current status of GHG emissions science (AARD, et. al., 2003). This research highlighted the current knowledge on GHG emissions as well as some of the important knowledge gaps. The following summaries were adapted from the Alberta Agriculture and Rural Development and the University of Alberta study highlighting the known GHG mitigation practices for cattle and pasture management:

*Summary of Known Factors Influencing Greenhouse Gas Emissions from Cattle Production:*

- Methane emissions are influenced by species, animal type within species, weight, composition of diet, location, time of year, days on feed, productivity level and age.
- Beef cows emit more CH<sub>4</sub> than beef calves.
- Management for increased production efficiency reduces GHG production per unit production.
- Feed testing and ration balancing lead to reduced GHG emissions in livestock production systems.
- Cattle on forage-based diets produce more CH<sub>4</sub> than cattle on grain-based diets. Feeding higher-quality forages reduces CH<sub>4</sub> production from cattle.

*Summary of Known Factors Influencing Greenhouse Gas Emissions from Pasture / Grazing Management:*

- Soils will sequester carbon if net primary production exceeds soil respiration.
- Converting annual cropland to perennial forage decreases net GHG emissions by sequestering more carbon. Perennial grasses sequester more carbon than annual crops because of their fibrous root system. Perennial grasses store more soil carbon than perennial legumes.
- Nitrogen application rates based on soil nitrogen testing and grass requirement reduce N<sub>2</sub>O emissions and increase carbon sequestration.
- Overgrazing exposes soil, creating conditions similar to fallow, therefore increasing soil carbon mineralization.
- Managed pasture (rotational grazing, fertility management, stocking rates, and residual biomass) results in lower total net GHG emissions than unmanaged pasture.

Source: (AARD, et. al., 2003).

Three key areas of focus offer potential to reduce greenhouse gas emissions of methane and nitrous oxide:

- Cattle feed and genetics
- Grazing management
  - Types of plants
  - Rotational grazing
  - Fertilization of pasture
- Conversion of marginal crop land to pasture

These three areas will be the focus of the scientific review of recommended practices to reduce GHG emissions from grazing cattle.

## Review of GHG Emissions Science

A variety of research projects have led to some form of beneficial management practice for reducing GHG emissions in cattle and other livestock. For the purpose of this paper however, the research review will be restricted to the three key areas for grazing cattle.

### Cattle Feed and Genetics

Feed efficiency is a significant component of the unit cost of beef cattle production, with a 5% improvement having an economic impact four times greater than a 5% improvement in average daily gain (Basarab, 2004). Two ways to improve feed efficiency are to use higher quality feed and to have animals that can use feed more efficiently.

Research has been conducted on the feed efficiency or residual feed intake (RFI) of beef cattle, suggesting that animals with low RFI grew as rapidly as animals with high RFI but consumed less feed and produced few GHG emissions. Residual feed intake (RFI) is the difference between the actual and expected feed intake of an animal based on its body weight and growth rate over a specified period. The individual animal RFI can vary significantly above and below that expected or predicted on the basis of size and growth rate. Selecting animals with lower RFI measured post-weaning will lead to a decrease in feed intake by young cattle and by cows, with no compromise in growth performance or increase in cow size (Herd et al., 2003).

One research project reported that methane emission in a low RFI selected line of cattle was 28 and 24% less than for a high or medium selected line, respectively (Nkrumah et al., 2006). Another study found that second generation beef cattle selected for low RFI grew as rapidly as comparable animals selected for high RFI but produced 15% less methane and consumed 15% less feed (Herd et al., 2003). In both of these studies however, the test animals were in feedlot conditions and not grazing.

Genetic improvements in beef cattle would be expected to reduce enteric methane emission, particularly if the emission is expressed per unit live weight. Selecting animals for low RFI improves the feed efficiency in the off-spring relative to animals with a high RFI. Animals with a high rate of gain and not high feed efficiency will not be effective in reducing methane emissions of cattle (BTWG, 2005). Further research is needed to examine these genetic relationships and to find ways for cost-effective identification of superior cattle. Ranchers would benefit from selecting animals with low residual feed intake as input cost will decrease and emissions of GHG would decrease as well.

Another animal specific area for improvement that reduces GHG emissions is reproductive rates. A research study in Ireland suggested that maximizing dairy herd survivability would reduce the proportion of replacement stock in the herd and should lower methane emissions significantly (Berry et al., 2003). The study pointed out that the ability to breed animals that survive longer is of economic, welfare and environmental importance, and that with improved survival, the age structure of the herd is altered towards more mature animals that are expected to have higher yields. A United Kingdom study suggested that restoring fertility to greater levels seen in 1995 compared to the present (2003-4) would reduce methane emitted by between 10 and 11% and

that further improvements in fertility could reduce methane emissions by up to 24% (Garnsworthy, 2004). While these studies are based on dairy cows and in different climatic regions of the world, the ideas behind them are transferable.

A study in Canada for predicting methane emission of cow-calf herds was developed from information on feed consumption and predicted methane emission from cows, bulls, replacement heifers and calves in Canada using IPCC (Tier 2) conversion values (BTWG, 2005). For the analysis, a 17% replacement rate was assumed with reproductive rates set to vary from 80 to 90%. Reproductive rate was defined as the cows pregnant at the time calves are weaned in the fall and expressed as a percentage of the calves that were exposed to the bull during summer breeding. Similar reproductive rates among virgin heifers and mature cows and a cow:bull ratio of 25:1 were also assumed. As the reproductive rate varied from 90 to 80%, methane emissions per kg cow marketed decreased from 1012 to 938 g but it increased from 653 to 802 g per kg calf marketed. As expected, culling open cows at the time of pregnancy checking in the fall decreased methane emissions relative to delayed culling of open cows until the following spring. Total methane emission from a ranch with 100 cows and an 80% reproductive rate was 11.78 and 11.08 tonnes when culling in the spring and fall, respectively. Corresponding ranch methane emissions for a 90% reproductive rate were 11.47 and 10.77 tonnes. Table 3 shows the results from the project.

**Table 3 - Effect of Reproductive Rate and Culling Date on Methane Emission (g) from the Beef Herd.**

Culling Date:		Spring			Fall	
Reproductive Rate %	Per kg cow & calf marketed	Per kg cow marketed	Per kg calf marketed	Per kg cow & calf marketed	Per kg cow marketed	Per kg calf marketed
90	396.8	1011.8	652.8	372.5	949.7	612.8
89	400.1	1004.4	665.1	375.6	942.9	624.3
88	403.5	997.0	677.8	378.8	936.1	636.4
87	406.9	989.6	691.1	382.1	929.2	648.9
86	410.4	982.1	704.9	385.4	922.3	662.0
85	413.9	974.6	719.3	388.7	915.4	675.6
84	417.4	967.1	734.4	392.1	908.4	689.8
83	421.0	959.5	750.1	395.5	901.4	704.7
82	424.6	951.9	766.6	399.0	894.4	720.3
81	428.3	944.3	783.8	402.5	887.4	736.6
80	432.0	936.7	801.9	406.0	880.3	753.7

Adapted from BTWG, 2005

The type of feed cattle consume also impacts the rumen methane emissions. Feedlot cattle tend to release fewer methane emissions per animal than grazing cattle because grains can be digested easier and more efficiently. A variety of studies have been documented by the Beef Technical Working Group that reduce methane emissions from cattle, such as: enteric microbes; enteric methanogens; dietary supplements, such as fats and oils; and other additives affecting rumen microbes (BTWG, 2005). For the purpose of this paper, only supplements associated with grazing animals were reviewed. Most of the feed supplements either do not work in a grazing environment or are very expensive making them not practical.

Boadi et al. studied the effects of grain supplementation on methane production of grazing steers in 2002. The study concluded that the effects of grain supplementation on methane production was marginal in grazing steers, and suggested that pasture quality plays a major role in the extent to which methane production can be reduced with grain supplementation in grazing animals (Boadi et al., 2002). The study also compared methane emissions based on the pasture quality. This was determined by comparing early season pasture with mid season and late season conditions. Methane production declined with grazing on high-quality forages; steers on the early pastures had 44% and 29% lower energy loss as methane than animals on mid and late pastures, respectively. There was also a 54% lower CH<sub>4</sub> emission when animals entered new paddocks relative to those exiting the paddocks.

There is considerable variation in Canada among the levels of management and feeding found in beef cattle production on farms and ranches (BTWG, 2005). To determine the impact on methane emissions from all of these practices is not practical because some do not have an impact on methane emissions, while others might have an impact but are not currently measurable or predictable. Caution and careful judgment must be used to assess all the effects of level of management and feeding on methane output accurately (BTWG, 2005)

## **Grazing Management**

Grazing management offers potential to reduce GHG emissions by providing cattle with quality forage, as well as the ability to sequester carbon from the atmosphere. Key goals of range management are to maintain (Alberta Government, 2005):

- a diversity of native plant species, especially deep-rooted and productive forms
- vigorous healthy plants with well developed root systems
- adequate vegetative cover to protect soils from erosion and to conserve scarce moisture

These goals contribute to healthy rangeland and increase the potential for carbon sequestration and feed efficiency of the cattle. Range management principles are applied to maintain or foster healthy productive rangeland. These include (Alberta Government, 2005):

- balancing livestock demands with the available forage supply; the rancher harvests forage to produce red meat but leaves adequate ungrazed residue to protect plants and soil;
- promoting even livestock distribution by using tools like fencing, salt placement and water development to spread the grazing "load" over the landscape;

- avoiding grazing rangeland during vulnerable periods; early spring grazing can stress range plants when energy reserves are depleted as new growth is initiated;
- providing effective rest periods after grazing to allow range plants to recover from the stresses of grazing.

To determine the impacts of improving pastures, a study was conducted on the effects of forage type and fertilization on yield and quality of dryland pastures on the Canadian prairies (Kopp et al., 2003). The studied pastures contained either meadow brome grass or a mix of alfalfa and meadow brome grass that were either unfertilized or fertilized. Incorporating the alfalfa into grass pastures improved carrying capacity by 28% and met the nutritional requirements of lactating beef cows at no additional cost. The fertilization of meadow brome grass pastures improved the carrying capacity by 64% and met the nutrient requirements of lactating beef cows. Incorporating alfalfa with fertilization improved carrying capacity of pasture by 57% and met the nutrient requirements of lactating beef cows. Kopp et al. concluded that incorporating alfalfa and fertilizing or just fertilizing the meadow brome grass pasture included significant financial risk as they were only cost-effective strategies when precipitation was not limiting. The only treatment that did not have financial risk and was always a cost-effective treatment was the incorporation of the alfalfa into the meadow brome grass.

Chaves et al. (un-dated), concluded that methane production by grazing beef heifers was significantly affected by pasture type, depending on pasture site, an observation that likely is a reflection of differences in forage maturity and pasture composition. One of the observations was that as forage stands matured, their feed value decreased and methane emissions increased. Pasture composition also impacts methane emissions and cattle performance. In a presentation by Iwaasa (2006) at the Saskatchewan Beef Symposium, research indicated that newly established native grass pasture sequestered 2.12 mg/carbon/ha in just 4 years. Comparing two different native species mixes, a “simple” mix and a “complex” mix, Iwaasa found that, although dry matter production was greatest on the “simple” mix site, animal performance was greatest when grazing the “complex” mix.

Efforts to reduce GHG emissions from manure have resulted in research on composting manure piles. Most studies have only looked at the potential GHG emissions reduction from composting as opposed to using raw manure. Research results have indicated that composting manure does result in reduced GHG emissions, particularly for methane emissions and that stockpiling resulted in 1.46 times more GHG emissions than composting (Pattey et al., 2005). Butler et al. (undated) applied dairy manure compost to tall wheatgrass and determined the compost was beneficial.

Several prairie researchers have found that forage quality can influence the amount of methane emitted per unit of animal productivity or unit live weight gain. Manitoba researchers have found that when pastures are managed to ensure forage quality is high, methane production per unit basis of beef production can be reduced as much as 20% compared to poor quality forage (McCaughey, 1999). The study found methane output was only 7.1 % of GE as opposed to 9.5% with mixed alfalfa/grass pastures as opposed to grass only pastures. The chemical composition of pasture types and sampling periods differed resulting in different diets for the cows. The dry matter intake was greater for cows grazing alfalfa–grass pastures than for cows grazing grass-only pastures. However, methane production was greater for cows grazing alfalfa-grass pastures

than for cows grazing grass-only pastures. The result was the energy lost through belching of methane was less for cows grazing alfalfa–grass pastures than it was for cows grazing grass-only pastures. Many of the reasons for differences in methane output of different forages would relate to chemicals such as tannins and saponins found in different forages (BTWG, 2005).

Another study compared the stocking rate and rotational or continuous grazing. Crossbred yearling steers grazed 60% alfalfa, 40% grass pastures and were managed by rotational or continuous grazing at each of heavily-stocked and lightly stocked rates (McCaughey, 1997). Methane emissions were measured using the SF<sub>6</sub> tracer gas method. The continuously grazed, heavily stocked pasture resulted in lowest methane emissions per animal at 174.4 g/hd/day, while the highest emissions per animal were 220.8 g/hd/day from the continuously grazed, lightly stocked pasture. Methane production per hectare, was calculated as 523.6 litres/ha/day for the continuously grazed heavily-stocked rate site vs. 331.6 litres/ha/day for the continuously grazed, lightly stocked pasture. However, when methane production measurements were compared on a kilogram of body weight basis, no differences were found between grazing treatments.

While some grazing studies have focused on the ability of high quality pastures to reduce methane emissions from the cattle, other studies have examined the potential of the pasture to sequester carbon from the atmosphere.

Three experiments were conducted between 2003 and 2005 in central and southern Saskatchewan to determine GHG emissions and soil carbon as affected by factors such as landscape element, grazing and shrub invasion (Bai et al., 2005). The areas studied include the Mixed Grassland and Moist Mixed Grassland Ecoregions within the Prairie Ecozone. The study concluded that grazing did not significantly affect soil organic carbon and root biomass, even though soil organic carbon tended to be lower at the grazed sites than the ungrazed. Soil carbon was controlled more by soil texture than by shrub cover or grazing, with loamy soils having greater potential for soil organic carbon than sandy soils. GHG emissions from native grasslands are relative small compared to other vegetations. Changes in vegetation from grassland to shrubland increased above-ground biomass but not soil organic carbon. The study summarized that current management practices aiming at sustainability and integrity of grassland ecosystems should be maintained, since properly managed mixed-grass Prairie has a well-balanced nutrient cycle that includes various GHGs. The grassland ecosystem plays a role in the dynamic flow of GHG's by retaining carbon that would be released to the atmosphere with poor grazing management or the conversion to arable agriculture.

A current study investigating the effects of livestock grazing management on the Shortgrass Steppe and CO<sub>2</sub> exchange concluded that changes in plant community due to species shifts under moderately and heavily–grazed pastures can alter the seasonal sequestration of carbon (Morgan, 2005). The study also suggested that recommended grazing practices do not notably alter the seasonal carbon exchange when compared to ungrazed pastures. The study noted that while the Shortgrass Steppe may be resilient in the long-term to grazing, in the short-term, livestock removal or reductions in stocking rate may be important for maintaining a positive carbon balance in the face of drought.

Light to moderate grazing on both mixed grass and short grass resulted in a richer diversity of plant species than when grazing is excluded (Reeder et al. 2001). Ungrazed pastures result in weedy annual forbs and grass that do not have dense root systems, which are conducive to carbon sequestration. Heavy grazing tends to decrease plant species diversity. Grazing a light to moderate stocking rates resulted in stable, diverse plant communities dominated by forage grasses with dense, fibrous rooting systems that promote soil organic formation and carbon sequestration in the soil.

Lynch et al. used the GrassGro model to estimate the influence of improved grazing practices on soil organic carbon, and farm profitability, across native rangelands and tame pastures of the southern Canadian Prairies. The GrassGro model is a computer simulation of management-induced changes in range and pasture forage and livestock productivity. The model was combined with spreadsheet analyses to estimate improved practices included complementary grazing<sup>2</sup> (CG) and reduced stocking density (RSD) on rangeland; and nitrogen fertilization (FERT), seeded grass/legumes grazed continuously (GLGC) or rotationally (GLGR), and RSD on tame pastures (Lynch et al., 2005). The complementary grazing prevents overgrazing of pasture and allows for optimal forage use when the pastures and rangelands are at prime quality.

The analysis was conducted over three eco-regions on the basis of similarities in climate and soil type. Results were averaged over 30 yr and the three eco-regions. The soil sequestration rates from the improved management were 5 kg C/ha/yr for the RSD and up to 26 kg C/ha/yr for CG on rangelands, and 86 kg C/ha/yr for RSD, 75 kg C/ha/yr for GLGC, 62 kg C/ha/yr for GLGR and 222 kg C/ha/yr for FERT on tame pastures (Lynch et al., 2005). The study noted that the gains with FERT were considered largely negated by associated energy costs, N<sub>2</sub>O emissions, and shifts in grassland species. The conclusion from the GrassGro model was that the complementary grazing system alone improved net returns to the producer.

For this system to work, Lynch et al. suggested that more research is required to determine the most cost-effective method of seeding alfalfa and other legumes into improved tame pastures, including no-till methods such as frost seeding, feeding of the seed to cattle, or seed drilling with a no-till drill.

## **Conversion of Cropland to Pasture**

Soil conservation on agricultural lands has been widely promoted in Canada as a method to sequester carbon dioxide from the atmosphere, as well as improve soil quality. The adoption of soil conservation practices is increasing in Canada as many agriculture producers have begun to shift from conventional tillage and land management practices to more zero tillage, reduced summerfallow frequency, complementary and rotational grazing systems, and perennial crop production (Boehm et al., 2004).

The conversion of cropland to pasture or permanent cover and improved management of grazing lands enhances soil carbon sequestration by reducing soil disturbance and organic matter decomposition and increasing the amount of plant biomass carbon added to the soil (Boehm et al., 2004). The change in management practice will increase the carbon sequestration rate, but

---

<sup>2</sup> Complementary grazing uses tame grass or annual crop pastures to add to or complement native range pastures.

the soil organic carbon levels will reach equilibrium with the rates of carbon inputs and losses associated with the sink-enhancing practices stabilizing after about 20 years.

A study compared how tillage frequency and the presence of permanent grass cover influenced the accumulation of carbon in a Brown Chernozem soil. Four management practices: fallow-wheat (FW), fallow-wheat-wheat (FWW), continuous wheat (W) and permanent grass (G) rotations were studied for six years (Bremer et al. 2002). Using the fallow-wheat as the baseline, the carbon sequestration rates were higher in the other rotations. The permanent grass system was 3.0 Mg C /ha over the six years. This study demonstrated that in terms of absolute amounts, permanent grass facilitates greater carbon sequestration. However, the sequestered carbon in the permanent grass will be subject to mineralization and return to the atmosphere should the permanent grass system be tilled again and revert to annual crop production.

Table 4 demonstrates some of the predicted carbon sequestration rates for several of the practices. The rates identified for zero tillage and reduce summerfallow were developed from empirical data, while the other rates were developed using the CENTURY model (Boehm et al., 2004). The CENTURY model is a computer model of plant-soil nutrient cycling which has been used to simulate carbon and nutrient dynamics for different types of ecosystems including grasslands, agricultural lands and forests.

**Table 4 – Carbon Dioxide Sequestration Rates for Soil Conservation Practices**

Activity	Prairie Soils (tonnes CO <sub>2</sub> /ha/yr)		
	Brown Soils	Dark Brown Soils	Black soils
Zero Tillage	0.73	0.73	1.34
Reduce Summerfallow	0.15	0.16	0.08
Permanent Cover	0.88	1.15	3.3
	Ecoregions		
	Montane Cordillera	Boreal Plains	Aspen Parkland
Improved Grazing Management			
Seeded Pasture	0.07	0.41	0.33
Native Pasture	0.13	0.14	0.10

Source: Boehm et al., 2004

These estimates do not include the impact of the other GHG emissions from N<sub>2</sub>O and CH<sub>4</sub>. The soil conserving practices are estimated to cause an increase in methane and nitrous oxide emissions of between 0 and 14 million tonnes CO<sub>2</sub>-equivalent over the first commitment period, depending on the adoption rates of related activities (Cohen R. undated). This will partially offset the removals of CO<sub>2</sub> in soil carbon. For a carbon-sequestering land management practice to be beneficial in terms of GHG emissions reduction, the associated incremental N<sub>2</sub>O and CH<sub>4</sub> emissions have to be less than the sink potential. An increase in permanent cover through pasture lands and livestock production will increase soil carbon. However, the carbon sink must be considered in relation to the GHG emission implications of the entire system. An increase in livestock production will cause methane emissions from cattle to increase and N<sub>2</sub>O and CO<sub>2</sub>

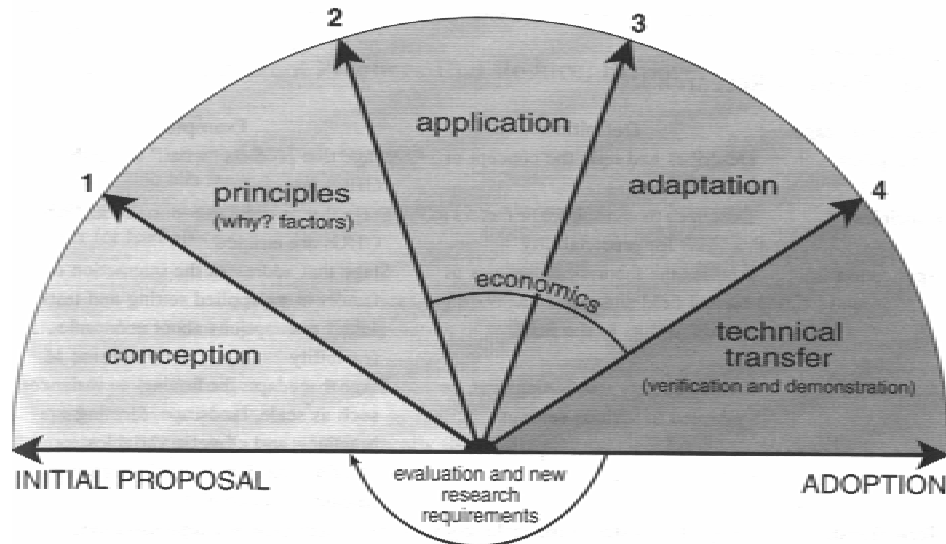
emissions associated with crop production inputs to decline. The mitigation potential of a sink-enhancing practice will depend on the relative amount of the sink/emission reduction and the emission increase.

## Research Knowledge Gaps

A variety of research activities have been reviewed indicating the science is starting to support several of the beneficial management practices highlighted to reduce greenhouse gas emissions from grazing cattle. There are still a number of unanswered questions before many of these practices can be used with confidence on the ranch. This section of the paper highlights some of the knowledge gaps associated with grazing cattle GHG emissions using a framework based on the research cycle.

Burton and Sauvé developed an approach to assess GHG emissions research based on the five stages of research (Burton and Sauvé, 2006). For this framework, the five stages of research are represented by: conception, principles, application, adaptation and tech transfer. The conception stage outlines and tests the concept or research hypothesis. The principles stage describes the factors used for predicting results. The application stage applies the theoretical findings to actual field situations. The adaptation stage describes how the research findings can be adapted to various field settings. The final research stage is tech transfer, which supports the transfer of the technology to the farm. Categorizing the technology into one of the five research stages provides researchers and policy makers an understanding of how much work is required before the technology can be used in the field. Figure 2 demonstrates the five stages of research in graphical format.

**Figure # 2 – The Five Stages of Research**



Source: Burton and Sauvé, 2006

Using the framework, the agricultural practices identified through the review of the GHG science will be assigned a research stage and the research knowledge gap highlighted. Table 3 is the summary of the agricultural practices with their current research stage and knowledge gaps.

**Table 3 - Potential Management Practices That Reduce GHG Emissions**

Agricultural Practice	Research Stage	Research Gap
<b><i>Cattle Feed and Genetics</i></b>		
Select animals for low RFI	Application /Adaptation	Need more research on the overall GHG balance  Need to be able to measure low and high Residual Feed Intake in field settings
Increase cow reproductive rates	Adaptation	Need further research on actual GHG emissions from the different animals
Improve pasture quality	Adaptation	Need more information on economics and other GHG emissions associated with the specific practices
<b><i>Grazing Management</i></b>		
Forage mix for improved pasture	Adaptation	Research is required on more plants as well as other GHG emissions associated with the forage mix
Fertilization of pasture	Adaptation	More information is required on the potential for other GHG emissions as well as climatic impacts such as moisture
Compost manure on pasture	Principle	Research is required in this area
Stocking Rates	Adaptation	Need more information on the impact of carbon sequestration from different stocking rates and different regions of Canada
Rotational and continuous grazing	Application	More information is required on GHG emissions and carbon sequestration as a result of rotational and continuous grazing
<b><i>Conversion of Cropland to Pasture</i></b>		
Convert marginal cropland to pasture, grassland	Adaptation	Need more information on GHG emissions from conversion to other land-uses, i.e. the addition of livestock to the pasture

## **GHG Reducing Agricultural Practices Assessment**

While research studies are reviewing certain management practices which can reduce GHG emissions from specific sources, more information is required on some of the unintended or secondary impacts on GHG emissions from other sources. The overall impact of the suggested practices should be understood before efforts are made for wide scale adoption of GHG reducing agricultural practices. For producers to adopt some of the practices, more effort is required to highlight the economic, social and environment benefits of the practice. Many of the practices highlighted in this paper have other benefits as well as costs associated with them.

Very few of the GHG studies discussed the impact of the practice in terms related to a business activity. From a beef cattle business perspective, questions about meat quality, production performance, cost of implementation of the practice, and associated risks tied to the practice are just some of the necessary issues to be considered before making the decision to adopt the practice.

Lynch et al., 2005 and Kopp et al., 2003 reviewed the cost effectiveness of improving pasture through fertilization and mixed forages. Both studies concluded the most reliable approach was the introduction of alfalfa into the pasture. While other methods could be cost effect, such as the additional of nitrogen fertilizer, the results indicated the risk of precipitation variables negated the benefits.

These were the only studies reviewed that started to address the business component of the decision to adopt practices to reduce GHG emissions from grazing cattle.

## Conclusions

Research in the area of grazing management to reduce GHG emissions is relatively recent. A number of suggestions have been made that theoretically should reduce GHG emissions, but more research is required before this information can be used effectively for international or national GHG emission reduction agreements. Most of the research is still in the adaptation stage, requiring the practice to be confirmed in a variety of field tests.

A number of the practices highlighted also have other benefits associated with them that could make the justification for their use already. Improving feed efficiency, for example, while beneficial for methane emissions reduction, also reduces the input costs of production. Improving the quality of the pastures reduces methane emissions from the cattle but also reduces the required amount of feed supplements and input costs. Some of this information is already available to producers making decisions on the farm. Some of the practices are little more than good farm management and can be applied with little change to normal activities.

Some of the suggested practices need to be evaluated on a case by case basis. Converting cropland into pasture, for example, might be appropriate for many of the farms, but a detailed analysis would be required on the farm to ensure the economic, environmental and social benefits exceed the costs.

For producers to be able to use the research developed around GHG emission reduction and carbon sequestration, more of the information required about the business decisions needs to be included. Without a current market for trading emissions reduction and GHG sequestration credits the incentives to adopt the practices will need to rely on other benefits.

## References

Alberta Agriculture, Food and Rural Development and University of Alberta, *Development of a Farm-Level Greenhouse Gas Assessment: Identification of Knowledge Gaps and Development of a Science Plan*. Alberta Agriculture Research Institute Project Number 2001J204. 2003.

Alberta Government, *Range and Pasture Management: Alberta Rangelands*, Sustainable Resource Development, Alberta Government, 2005.  
[http://www3.gov.ab.ca/srd/land/pdf/Range\\_Health\\_Field\\_Workbook.pdf](http://www3.gov.ab.ca/srd/land/pdf/Range_Health_Field_Workbook.pdf)

Bai, Yuguang, J.T. Romo, Brain McConkey, Dan Pennock, Richard Farrell, Tyler Colberg and Matthew Braun, *Reducing Greenhouse Gas Emission in Rangelands Through Landscape-based Management*, Final Report Submitted to the Saskatchewan Agriculture Development Fund Project-20020082, by the Department of Plant Sciences, University of Saskatchewan, Saskatoon Saskatchewan, Canada, 2005.

Baron V.S., D.J. Young, W.A. Dugas, P.C. Mielnick, C. La Bine, R.H. Skinner, and J. Casson, *Net Ecosystem Carbon Dioxide Exchange over a Temperate, Short-Season Grassland: Transition from Cereal to Perennial Forage*, in *Climate Change and managed Ecosystems* editors J.S. Bhatti, R. Lal, M.J. Apps, and M.A. Price, Taylor and Francis New York, 2006.

Basarab, John, Erasmus Okine, and Stephen Moore, *Residual Feed Intake: Animal Performance, Carcass Quality and Body Composition*, 2004 Florida Ruminant Nutrition Symposium, 2004.

Berry, D.P., F. Buckley, P. Dillon, R.D. Evans, M. Rath and R.F. Veerkamp. *Genetic selection to maximize dairy herd survivability*,  
<http://www.irishgrassland.com/2003/Journal/Dairy/Dairy%20Donagh%20Berry.PDF>

Boadi, D.A., K.M. Wittenberg and W.P. McCaughey, *Effects of grain supplementation on methane production of grazing steers using the sulfur (SF<sub>6</sub>) tracer gas technique*. Canadian Journal of Animal Science 2002. 82:151-157.

Boadi, D.A., K.H. Ominski, D.L. Fulawka, and K.M. Wittenberg, *Improving Estimates of Methane Emissions Associated with Enteric Fermentation of Cattle in Canada by Adopting an IPCC (Intergovernmental Panel on Climate Change) Tier-2 Methodology*, Final report submitted to the Greenhouse Gas Division, Environment Canada, by the Department of Animal Science, University of Manitoba, Winnipeg, Manitoba, Canada, 2004.

Boehm, Marie, *Afforestation on the Prairies - Opportunities and Challenges: Agriculture and Carbon Sequestration*, Presentation for the Feasibility Assessment of Afforestation for Carbon Sequestration (FAACS) Initiative, a Pilot Project of the Manitoba Forestry Association, 2003

Boehm, M., B. Junkins, R. Desjardins, S. Kulshreshtha and W. Lindwall, *Sink Potential of Canadian Agricultural Soils*, Climatic Change 2004. 65: 297 - 314

Bremer, E., Janzen, H. H. and McKenzie, R.H., *Short-term impact of fallow frequency and perennial grass on soil organic carbon in a Brown Chernozem in southern Alberta*. Canadian Journal of Soil Science 2002 82: 481-488.

Burton, D. and J. Sauvé, *Identifying and Addressing Knowledge Gaps and Challenges Involving Greenhouse Gases in Agriculture Systems under Climate Change*, in Climate Change and managed Ecosystems editors J.S. Bhatti, R. Lal, M.J. Apps, and M.A. Price, Taylor and Francis New York, 2006.

Butler, T.J. and J.P. Muir, *Dairy Manure Compost Improves Soil and Increases Tall Wheatgrass Yield*, Texas Agricultural Experiment Station, A&M University Research & Extension Center, undated.

Chaves, A., L. C. Thompson, A. D. Iwaasa, S. L. Scott, M. E. Olson, C. Benchaar, D. M. Veira and T. A. McAllister, *Effect of pasture type (alfalfa vs. grass) on methane and carbon dioxide production by yearling beef heifers*, Submitted to Canadian Journal of Animal Science, undated.

Derner, J.D., G.E. Schuman, M. Jawson, S. Shafer, J.A. Morga, H.W. Polley, G.B. Runion, S.A. Prior, H.A. Torbert, H.H. Rogers, J. Bunce, L. Ziska, J.W. White, A.J. Franzluebbers, J.D. Reeder, R.T. Venterea and L.A. Harper, *USDA-ARS Global Change Research on Rangelands and Pasturelands*, Rangelands 2005. 27: 36-42.

Derner, J.D., T.W. Bouton and D.D. Briske, *Grazing and ecosystem storage in the North American Great Plains*. Plant and Soil 2006. 280: 77-90.

Environment Canada, *Canada's Greenhouse Gas Inventory 1990-2003*, Greenhouse Gas Division, Government of Canada, April 2005.

Garnsworthy, P.C., *The environmental impact of fertility in dairy cows: a modelling approach to predict methane and ammonia emissions*, Animal Feed Science & Technology 2004. 112: 211-223.

Herd, R.M., J.A. Archer and P.F. Arthur, *Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application*, Journal of Animal Science 2003. 81:E9-E17.

Kopp, J.C., W. P. McCaughey, and K. M. Wittenberg, *Yield, quality and cost effectiveness of using fertilizer and/or alfalfa to improve meadow bromegrass pastures*, Canadian Journal of Animal Science 2003. 83: 291-298.

Lynch, D. H., Cohen, R. D. H., Fredeen, A., Patterson, G. and Martin, R. C. *Management of Canadian prairie region grazed grasslands: Soil C sequestration, livestock productivity and profitability*. Can. J. Soil Sci. 2005 85: 183-192.

McCaughey, W.P., K. Wittenberg and D. Corrigan, *Impact of pasture type on methane production by lactating beef cows*. Canadian Journal of Animal Science 1999, 79:221-226.

Morgan J.A., D.R. LeCain, D.P. Smith, J.D. Reeder, J.D. Derner, W.K. Lauenroth, W.J. Parton and I.C. Burke, *Livestock Grazing Management on the Shortgrass Steppe and CO<sub>2</sub> Exchange*, Colorado State University, 2005.

[http://sgs.cnr.colostate.edu/ProgressReports/2005\\_sitereview/booklet/Plant%20stuff/4MorganLivestockGrazingFinal.pdf](http://sgs.cnr.colostate.edu/ProgressReports/2005_sitereview/booklet/Plant%20stuff/4MorganLivestockGrazingFinal.pdf)

Moulin, A.P., P. McCaughey, D. McCartney, M. Entz, S. Bittman, and W.F. Nuttall, *Soil Carbon Sequestration in Pastureland and Rotation*, Presented at Manitoba Agronomists Conference 2002.

Muir, P.D., J. M. Deaker, M. D. Bown, *Effects of forage- and grain-based feeding systems on beef quality: A review*, New Zealand Journal of Agricultural Research, 1998, Vol. 41: 623-635.

Nkrumah, J.D., E. K. Okine, G. W. Mathison, K. Schmid, C. Li, J. A. Basarab, M. A. Price, Z. Wang and S. S. Moore, *Relationships of feedlot feed efficiency, performance, and feeding behavior with metabolic rate, methane production, and energy partitioning in beef cattle*, Journal of Animal Science 2006. 84:145-153

Ominski, Kim and Karen Wittenberg, *Strategies for Reducing Enteric Methane Emissions*, in Climate Change and managed Ecosystems editors J.S. Bhatti, R. Lal, M.J. Apps, and M.A. Price, Taylor and Francis New York, 2006.

Pattey, E., M.K. Trzcinski, R.L. Desjardins, *Quantifying the Reduction of Greenhouse Gas Emissions as a Result of Composting Dairy and Beef Cattle Manure*, Nutrient Cycling in Agroecosystems, 2005. 72: 173 - 187

Rayburn, E., *Meeting the Challenges of Pasture Finished Beef, Forage Management*, Extension Service West Virginia University, 2003.

Reeder, J.D., and G.E. Schuman, *Influence of livestock grazing on C sequestration in semi-arid mixed grass and short grass rangelands*, Environmental Pollution (2002) 116: 457-463.

Schuman, G.E., H.H. Jansen and J.E. Herrick, *Soil carbon dynamics and potential carbon sequestration by Rangelands*, Environmental Pollution (2002) 116: 391-396

Walker P. and A.D. Iwaasa, *Brief review on some GHGMP demonstration and research studies: what have we learned?*, Saskatchewan Beef Symposium, February 8-9, 2006