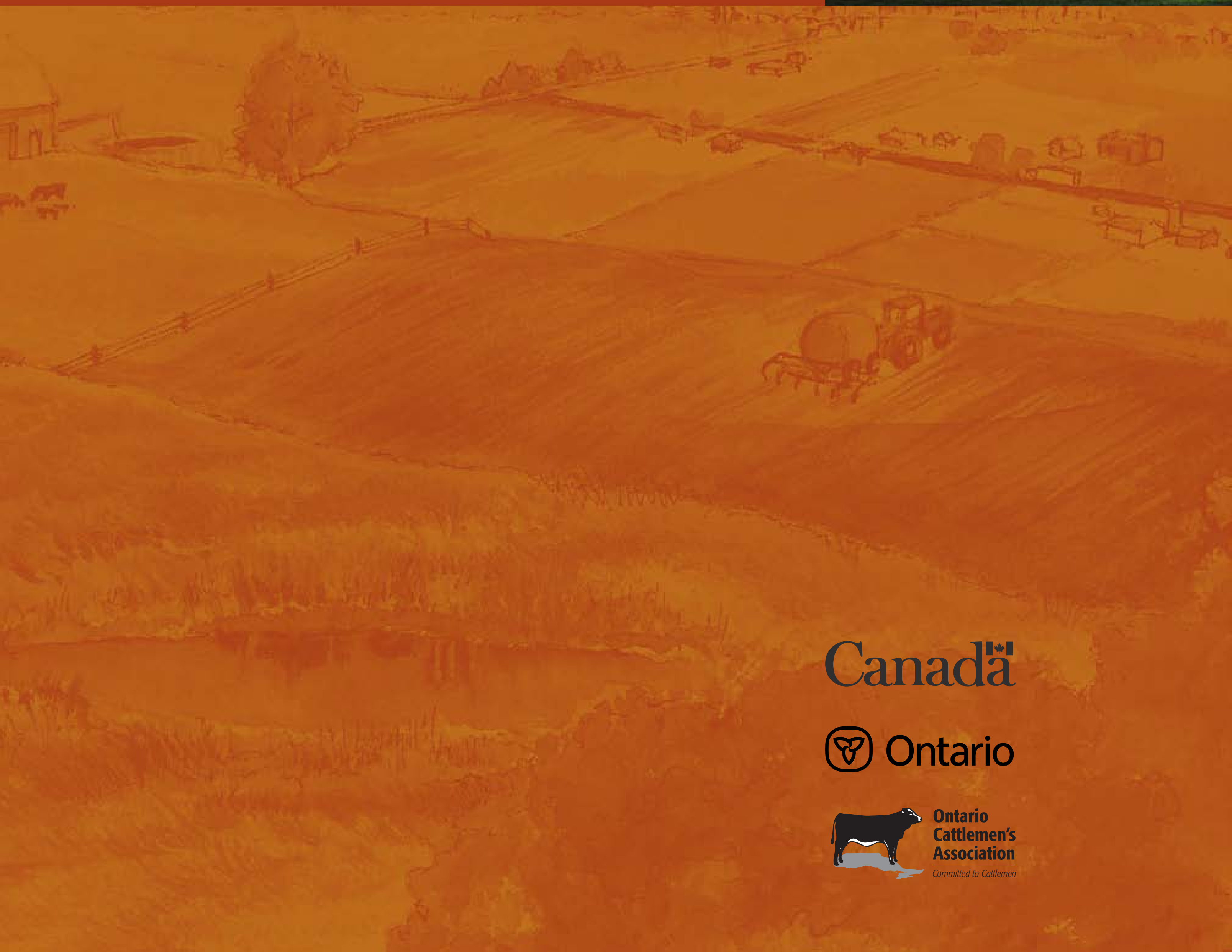
BEST MANAGEMENT PRACTICES

Greenhouse Gas Reduction in Livestock Production Systems



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Ontario Cattlemen's Association
Committed to Cattlemen

What is a Best Management Practice or "BMP"?

- a proven, practical and affordable approach to conserving soil, water and other natural resources in rural areas

Who decides what qualifies as a BMP?

- a team that represents many facets of agriculture and rural land ownership in Ontario, including farmers, researchers, natural resource managers, regulatory agency staff, extension staff and agribusiness professionals

What is the BMP Series?

- innovative, award-winning books presenting many options that can be tailored to meet your particular environmental concern and circumstances
- current BMP titles are:
  Buffer Strips
  Establishing Tree Cover
  Farm Forestry and Habitat Management
  Field Crop Production
  Fish and Wildlife Habitat Management
  Greenhouse Gas Reduction in Livestock Production Systems
  Horticultural Crops
  Integrated Pest Management
  Irrigation Management
  Livestock and Poultry Waste Management
  Managing Crop Nutrients
  Manure Management
  No-Till: Making It Work
  Nutrient Management
  Nutrient Management Planning
  Pesticide Storage, Handling and Application
  Soil Management
  Streamside Grazing
  Water Management
  Water Wells
  Woodlot Management

How do I obtain a BMP book?

- if you're an Ontario farmer, single copies of each title are available at no cost through the Ontario Ministry of Agriculture, Food and Rural Affairs
- to purchase single copies or bulk orders and to order complete sets of BMP books, please contact: Ontario Federation of Agriculture, Attn: Manager, BMP, Ontario Agricentre, 100 Stone Rd.W., Suite 206, Guelph, Ontario N1G 5L3. Phone: 1-800-668-3276
- for an on-line order form, go to: http://www.omafra.gov.on.ca/english/products/best.html
- please note that prices vary per title and with quantity ordered

CONTENTS

ABBREVIATIONS

BMP	Best management practice
C	Carbon
CH_4	Methane*
CO_2	Carbon dioxide*
GHG	Greenhouse gas(es)
N	Nitrogen
N_2	Nitrogen gas*
N_2O	Nitrous oxide
NH_3	Ammonia
NH_4^+	Ammonium
NO_3^-	Nitrate
NUE	Nutrient use efficiency
SOC	Soil organic carbon

* The main greenhouse gases. Methane has 21 times more global warming potential than carbon dioxide; nitrous oxide has 310 times the global warming potential of carbon dioxide.

INTRODUCTION

The more we learn about greenhouse gas and climate change, the more we, as energy consumers, understand that each of us can help reduce emissions.

The same is true for economic sectors. Power generation, manufacturing, transportation, and agriculture all contribute to the problem. With mounting public concern and research, these sectors acknowledge they have both a duty and an opportunity to tackle emission levels.

Why make changes for an outcome you can't see, measure, or take to the bank? There are good reasons, and they involve both long-term vision and short-term interest.

Agriculture appears well-positioned to make a difference. Properly managed, healthy soils may act as a "sink" to remove greenhouse gases from the atmosphere. Natural areas found on many farm properties, such as wetlands, woodlots, pastures and buffers, can also trap gases. Opportunities for on-farm green energy generation look promising. Studies are continuing to identify and quantify emission reduction measures.

In the meantime, as a farmer you can begin addressing a problem of planetary proportions in your day-to-day operations. The good news is that the practices that will help reverse global warming are accepted best management practices for productivity and sustainability. Here are some of the benefits.

Production efficiency. The best management practices that reduce emissions in fact do double-duty, promoting feed efficiency, reducing waste and saving you dollars.

Energy conservation, production and co-generation. While it's early days, with continual technological advancements, there is potential for harnessing energy.

The good news is that many practices that will help you achieve your goals, such as improved productivity, greater nutrition use efficiencies, and reduced impacts on water resources, also reduce greenhouse gas emissions.

Using anaerobic digestion technology, liquid manure can be processed to generate biogas for energy and to reduce methane emissions.

Future protection of animal agriculture. Climate change will eventually affect management decisions involving housing and energy systems, breed selection, preventative health measures, and drinking water systems. Although the agricultural season could be lengthened, crops could be threatened by extreme climatic events and northward expansion of infectious agents.

Societal stewardship. Like planting trees, the actions you take to reduce greenhouse gas emissions on your farm will benefit your children and their children. It's an investment, and all of us have to start somewhere.

Public perception and due diligence. As animal feeding operations expand and become more geographically concentrated, we can expect an upsurge in public concern regarding air emissions. By adopting some reasonable measures, you and the livestock and poultry sectors at large can get in front of would-be critics targeting animal agriculture vis-à-vis global warming. Better that producers actively seek and make improvements that are greenhouse gas and farmer-friendly – before less suitable "solutions" are imposed by regulations or the marketplace.

Public perception suggests that large livestock operations are key sources of air and water pollution – irrespective of the fact that most large operations are resource-efficient.

"When's the best time to plant a tree? Thirty years ago." Significant greenhouse gas reduction is a long-term proposition, and the time to start is now.

There's also reason to take heart. In the past decade, giant strides have been made in many facets of farming – tillage, genetics and feeding, for example – all of which will help cut on-farm emissions. And more information is coming on board all the time, including accurate measurements of emissions from many species of livestock, and the means to reduce emissions.

Researchers continue to look for reductions in greenhouse gas emissions from livestock production systems. The most promising options are those practices that improve efficiency, lower costs and provide other environmental benefits, too.

RISKS

Because this is a relatively new area of study, there are some unknowns you should be aware of:

- some greenhouse gas BMPs need more on-farm verification
- the impacts of some greenhouse gas BMPs have not been sufficiently documented
- a few of the practices that may reduce greenhouse gas emissions might increase the risk of nitrate movement (e.g., plowdown legumes in rotation).

HOW THIS BOOK IS ORGANIZED

To get off to the right start, it's helpful to understand some basic principles related to greenhouse gas and livestock agriculture. These are covered in the next chapter. From there we'll take a bird's-eye view of production systems. Then we focus on a livestock production system, one component at a time.

Beginning on page 18, we'll look at greenhouse gas BMPs for key components such as breeding, feeding, housing, quality control, and nutrient management. We'll explore how to fine-tune these components to reduce emissions.

As you read through, keep in mind there are many excellent reference materials that explain in detail the general BMPs as they relate to crop production and nutrient management. At the back of the book, there's a list of references and links to more information.

Cattle produce methane, which is a greenhouse gas. Methane is also an indication of feed inefficiency. Rations can now be fine-tuned to reduce methane and waste in feed.

THE BASICS – GREENHOUSE GASES AND AGRICULTURE

Climate change is linked to the emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide. While some greenhouse gases are naturally occurring, it's the increased levels of emissions that are of mounting concern. Global temperatures have risen 1.6°C, and global warming is directly related to elevated greenhouse gas levels.

Agriculture is the source of 9% of the global contribution of greenhouse gas. Of this amount, at least 65% is attributed to livestock agriculture: methane from ruminants and manure, nitrous oxide from stored manure, and carbon dioxide from all livestock, livestock housing and decomposing manure.

Key gases of concern are nitrous oxide, methane and carbon dioxide. The global warming potential of each compound is:

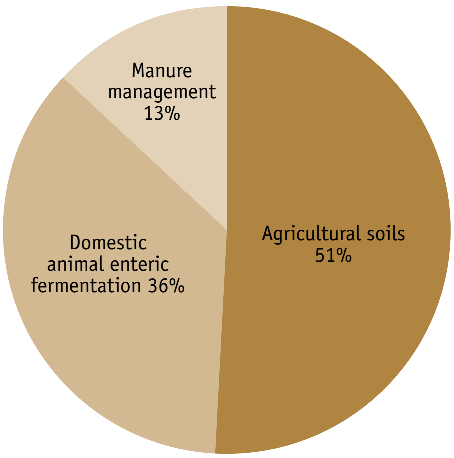
NITROUS OXIDE: METHANE: CARBON DIOXIDE (N_2O: CH_4:CO_2) = 321:21:1.

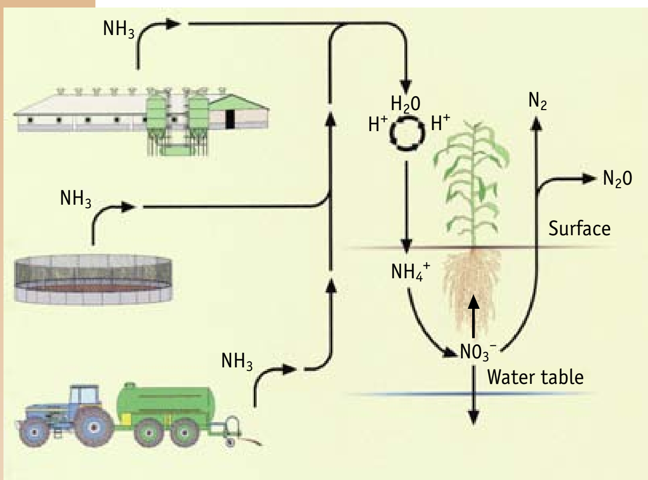
The net greenhouse gas-emissions from agriculture are usually caused by inefficient use of resources, such as feeds, energy, manure, land and water.

GREENHOUSE GAS EMISSIONS FROM THREE MAIN AGRICULTURAL SOURCES, IN CARBON DIOXIDE EQUIVALENTS

In 2003, GHG emissions from the agriculture sector contributed 8.4% of total national emissions. Total sector emissions rose 19% between 1990 and 2003. Emissions from manure management increased by 18% and from enteric fermentation by 20%. N_2O emissions from soils rose 19% over the same period.

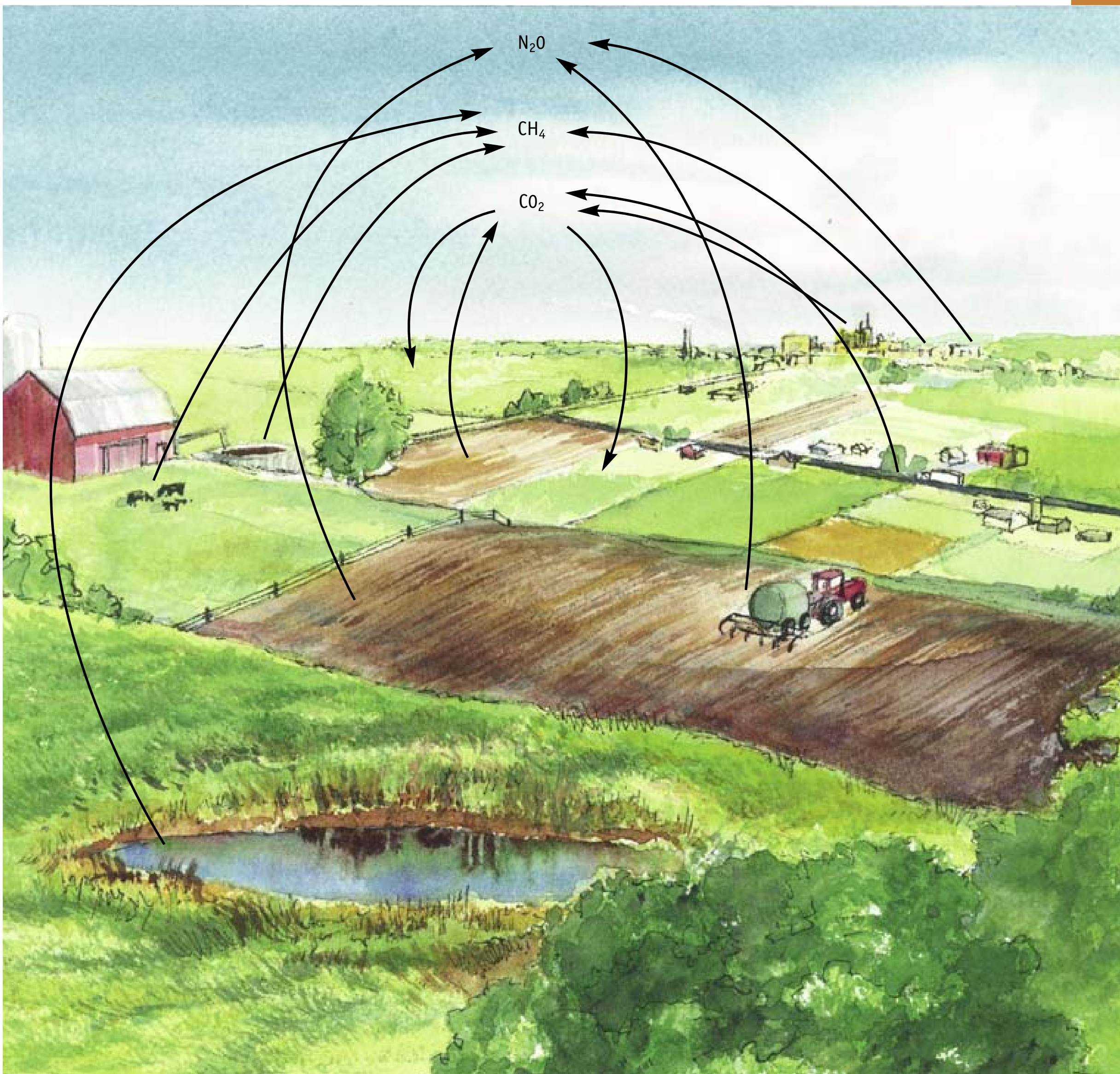
From Environment Canada Information on Greenhouse Gas Sources and Sinks, October 2005





Ammonia gas (NH_3) can indirectly contribute to the generation of nitrous oxide (N_2O) gas. Volatilized ammonia from barns, manure storages and applied manure will convert to ammonium (NH_4^+) as it reacts with moisture in the atmosphere. The NH_4^+ is redeposited throughout the landscape with precipitation. Most of this NH_4^+ will nitrify to nitrate (NO_3^-) in the soil.

The risk is that a significant amount of the nitrate will be converted (denitrified) to nitrogen gas (N_2) and nitrous oxides – particularly if deposition is NOT on cropland and NOT during the growing season.



Greenhouse gases (GHGs) are atmospheric gases that reflect heat energy released by Earth back to the surface. GHGs – water vapour, ozone, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) – are necessary for life on Earth. Without this natural greenhouse effect that "holds" some of the heat in our atmosphere, the average temperature on Earth would be too cold for life as we know it.

However, excessive increases in GHG levels can lead to a warming of Earth's surface. Some industrial, transportation, residential and agricultural activities accelerate the production of the three main GHGs (CO_2, CH_4 and N_2O), and therefore increase the risk of upsetting the atmospheric balance of GHGs.

Source: Greenhouse Gases and Ontario Agriculture, Infosheet #1, OMAF. AF095

IMPLICATIONS FOR AGRICULTURE

Climate change could lead to crop losses and shortages.

Prolonged drought could lead to fewer acres of sustainable pasture for grazing livestock.

Climate change could lead to long-term losses of readily accessible sources of drinking water.

Hotter summers could lead to increased incidence of heat stress for confined livestock.

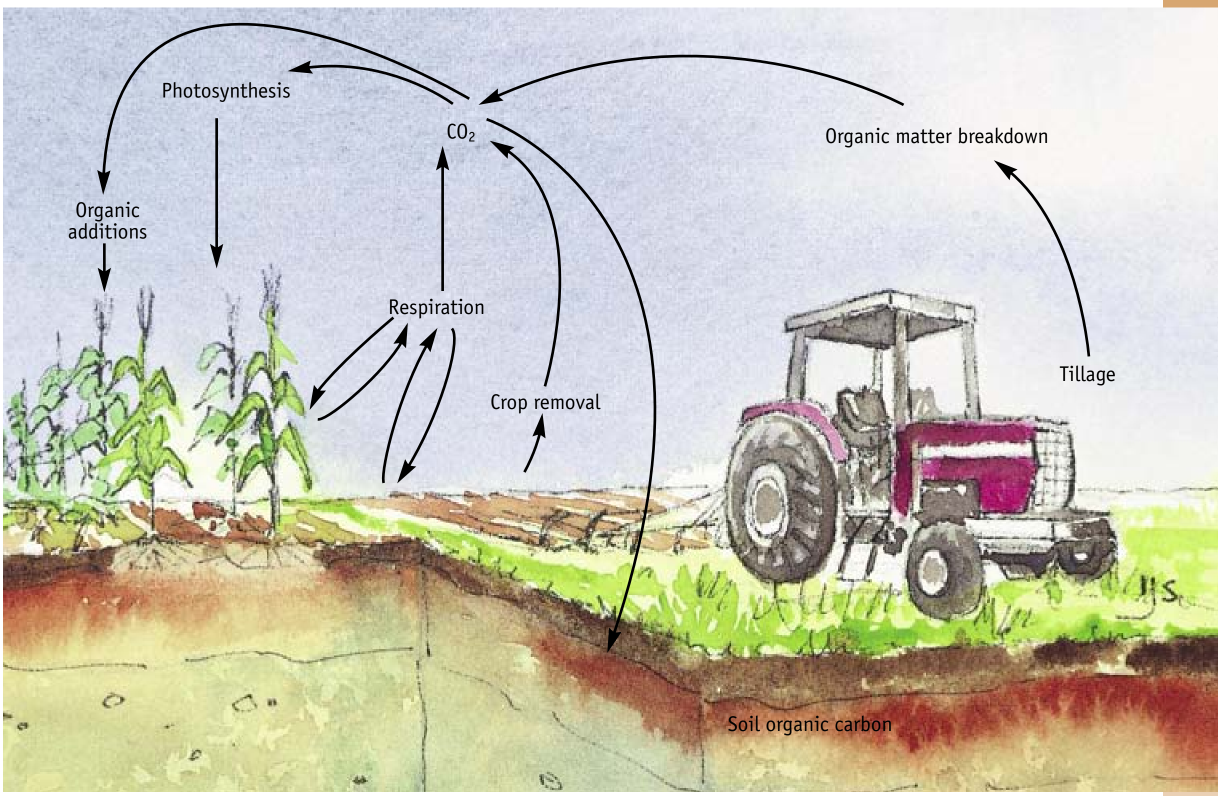
Impact of GHG Emissions on Livestock

- Global warming will mean higher temperatures and more drought
- Incidence of livestock heat stress will increase
- Pests and diseases will diversify and pressure will increase
- Feed prices will rise
- Pasture may be more difficult to establish and manage
- Drinking water will continue to be scarce in some regions
- Water quality will suffer in areas with low water levels

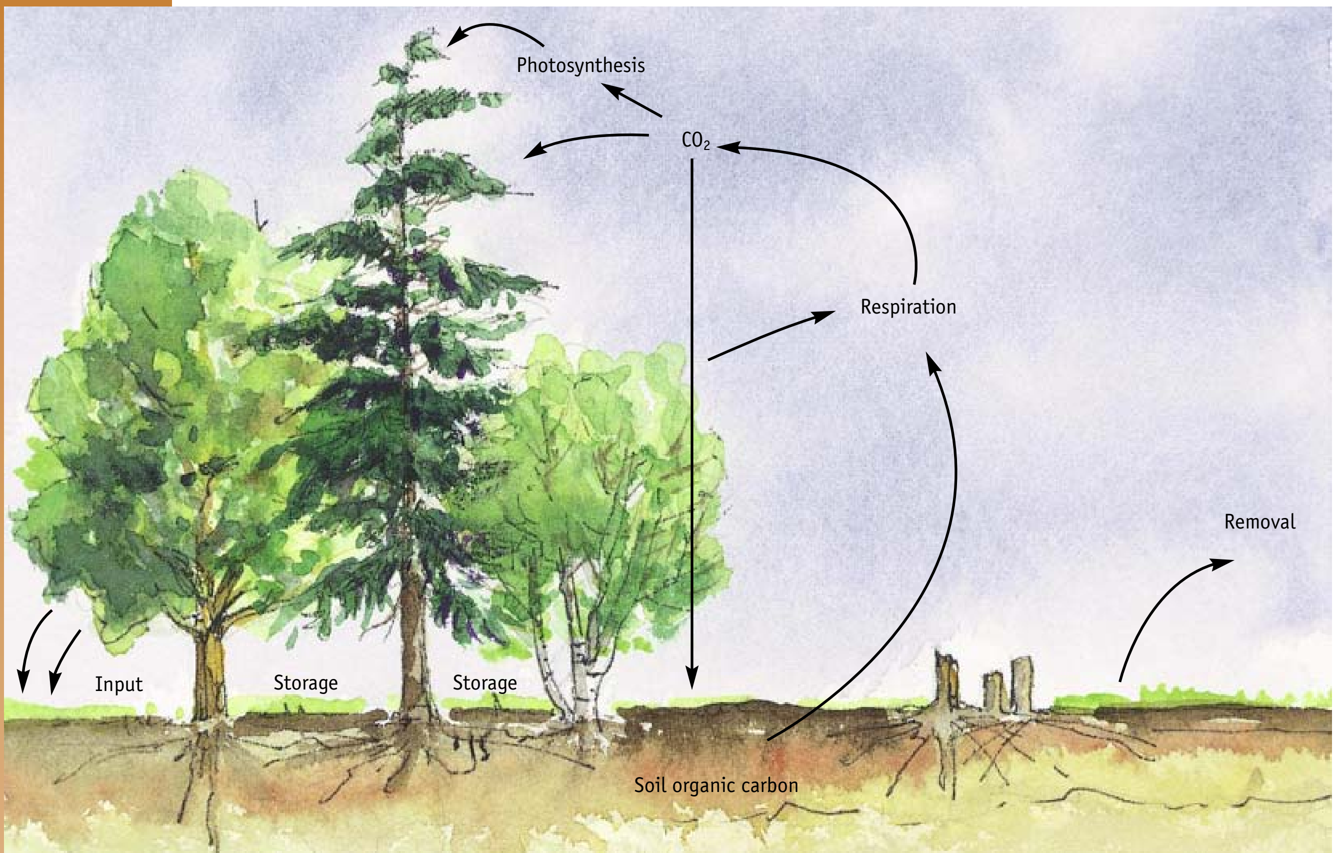
Agriculture and Agri-Food Canada

A sink is an invisible reservoir that absorbs released carbon. Trees, soils and wetlands are examples of potential sinks.

CARBON DIOXIDE (CO_2) GENERATION



Farming systems can be both a "sink" and a direct source for carbon dioxide. Crops and soils fix carbon dioxide. Tillage action and fuel consumption during field operations are a source of CO_2.

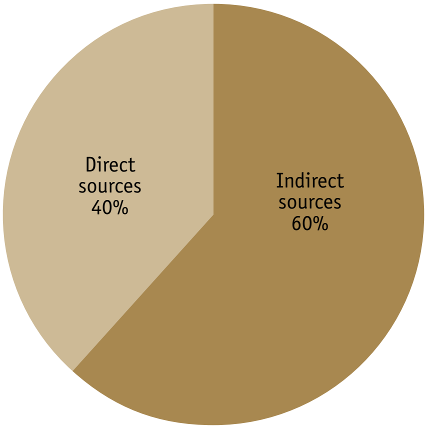


Farm woodlands are important sinks for carbon dioxide. Carbon is sequestered in woody plant material and woodland soils.

Carbon dioxide (CO_2) comes from direct and indirect sources. In the agriculture sector, direct sources account for 40% of the emissions – mostly from soil and fossil-fuel burning. Indirect sources account for the balance – mostly as energy used to develop inputs and as fuel for transportation.

Agricultural "gains" (meaning retention of carbon) are from photosynthesis. Carbon is fixed to form plant materials. Some plant materials go for human/livestock consumption, are respired to atmosphere, add to the soil organic carbon (SOC) or remain as plant tissue (fibre, wood). A significant proportion of agricultural crops – forages, pasture and grains – go to livestock feed.

"Losses" (meaning lost to the atmosphere as a greenhouse gas) are due to respiration by plants and livestock, methane emissions from livestock and soil loss (soil degradation), and fossil fuel combustion.



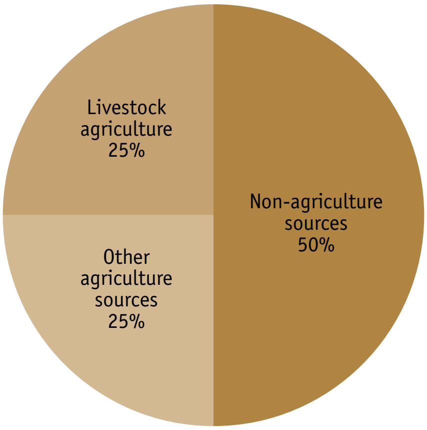
Direct sources – such as soil degradation (organic matter depletion) and fossil fuel use – contribute to approximately 40% of the CO_2 emissions from agriculture.

METHANE (CH_4) GENERATION

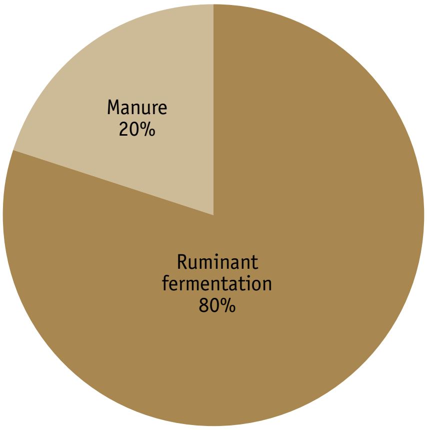
Methane is the principal component of natural gas. Because it has a short shelf life in the atmosphere, remedial measures can have a rapid impact.

Seventy per cent of methane comes from human activities. The remaining 30% is from natural sources. Half of the 70% is from agriculture, and half of that is from livestock agriculture.

Of livestock methane, 80% comes from ruminant fermentation and 20% from manure.



Livestock agriculture is the source of 25% of the methane emissions from human activities.

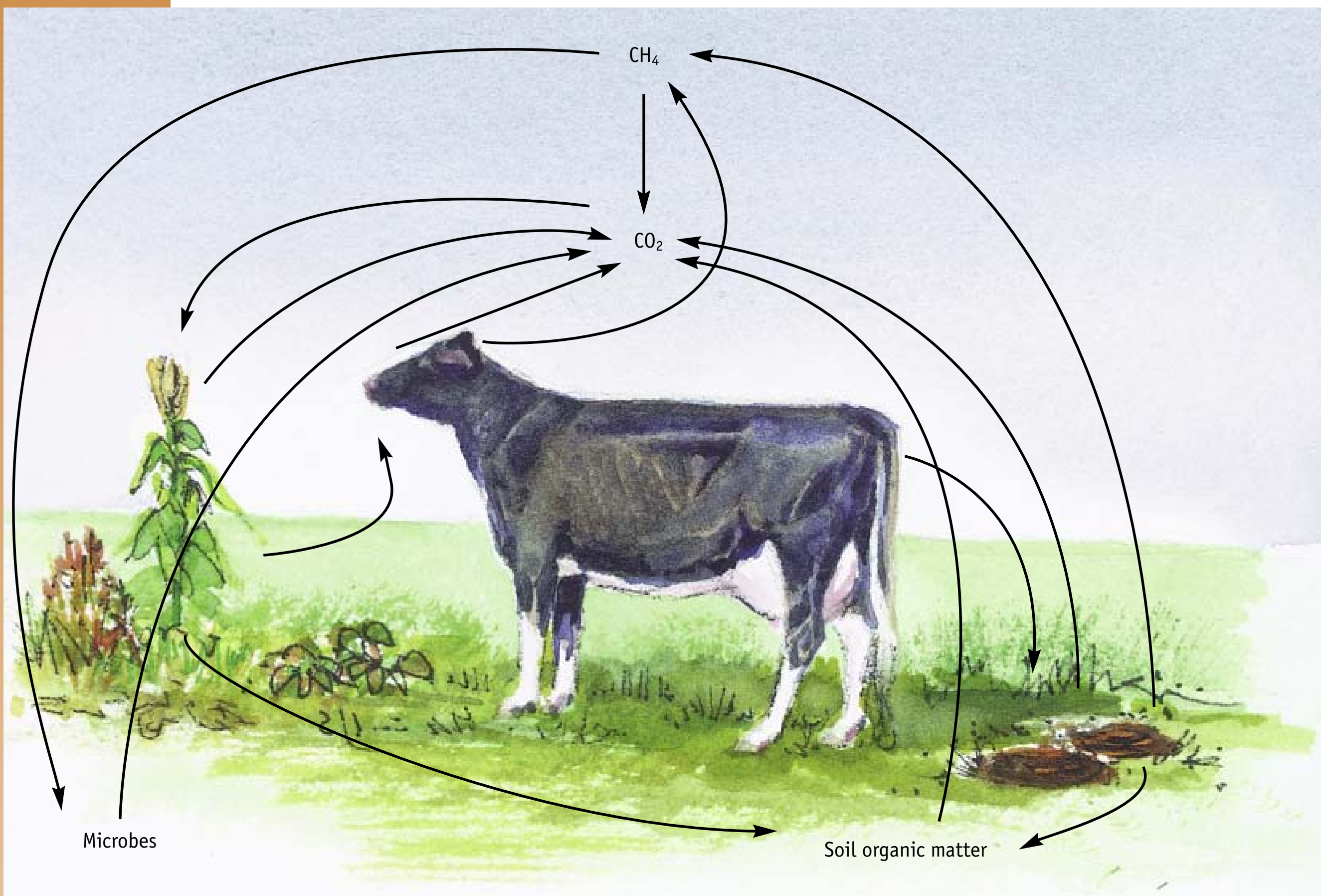


Eighty per cent of livestock methane emissions is from ruminant fermentation and 20% is from manure.

Approximately half of the methane from agriculture comes from livestock operations.

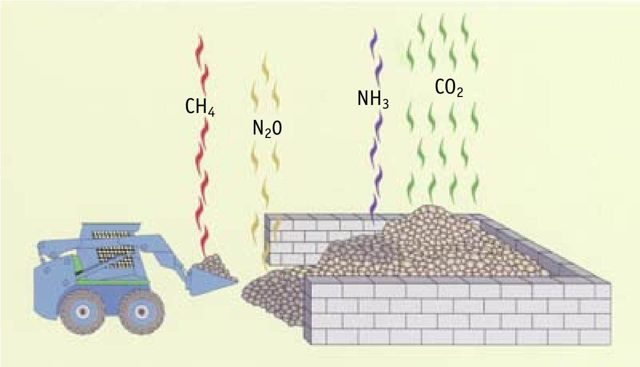
Microbes in the soil can convert up to 10% of atmospheric methane to carbon dioxide.

All types of livestock and poultry produce methane. Methane is a by-product of digestion – microbes that break down feed roughage emit methane. The greatest single source is ruminant livestock, e.g., cattle, sheep and goats. Their rumen, or fore stomach, ferments feeds, releasing methane and other gases. Cattle – by belching – generate most of the rumen-sourced methane from Ontario farms.



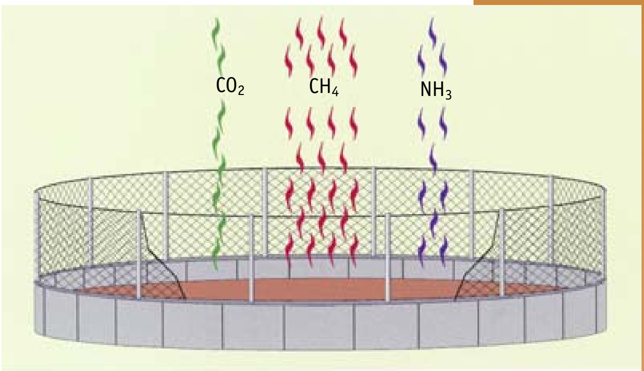
Carbon, in the forms of CH_4 and CO_2, is released by ruminants, decomposing manure, and decomposing soil organic matter. These losses can be reduced through improved management practices such as feeding strategies, as well as better manure handling and storage techniques.

Manure can decompose with or without oxygen. Either way, gases are released. With oxygen (i.e., aerobic environments such as solid manure stacks), microbes release carbon dioxide during decomposition. Without oxygen (i.e., anaerobic environments such as liquid storages, runoff storages and the wetter portions of solid manure stacks), methane is produced during decomposition.



Generally, the microbes in solid manure are aerobic and generate carbon dioxide. Methane and nitrous oxide are emitted from the wetter parts of solid manure piles.

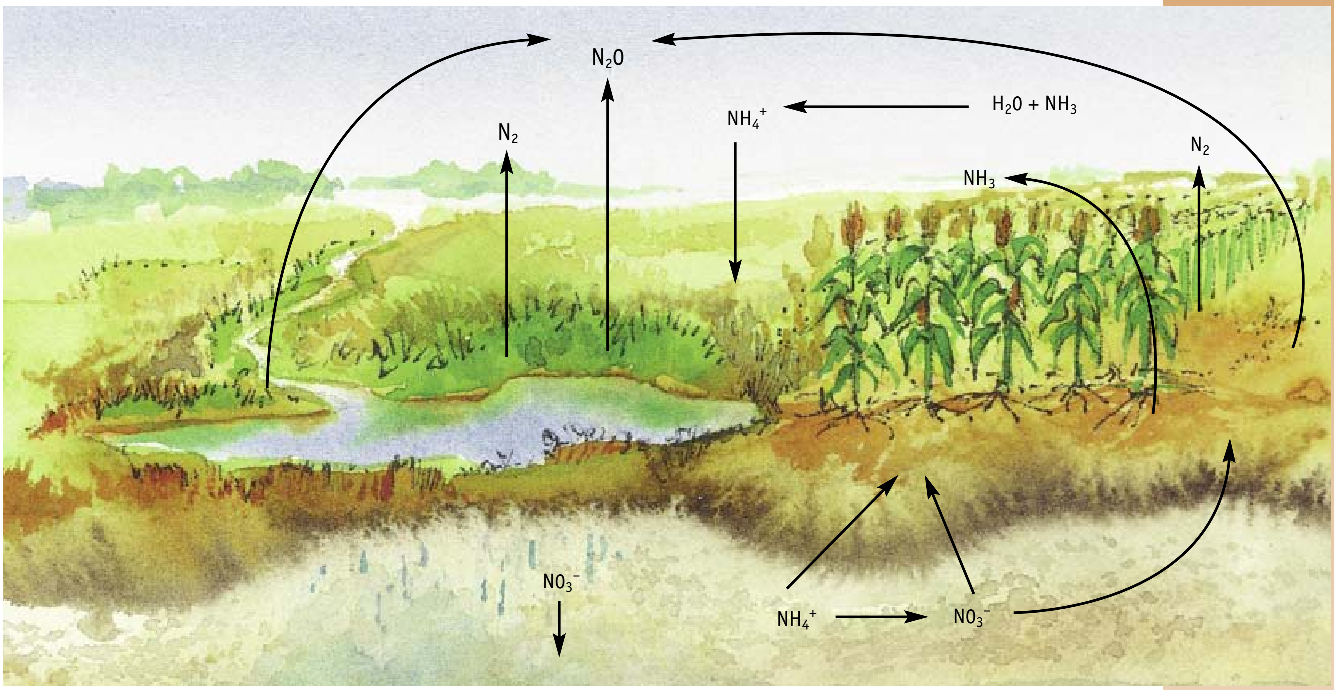
Methane and ammonia are emitted from liquid manure systems, which are mostly anaerobic.



NITROUS OXIDE (N_2O) GENERATION

Nitrous oxide or N_2O is the source of the largest share of greenhouse gas produced by agriculture. It's also the production component with the greatest opportunity for reductions.

There are two key sources of nitrous oxides from livestock production systems: **manure** and **soils**.



In agriculture, nitrous oxide (N_2O) is the greenhouse gas that has the most profound effect on climate change. There are two key sources: wet solid manure and partially denitrified N in soils.

NITROGEN (N) CYCLE

As nutrients, nitrogen and carbon are indispensable agents for promoting crop growth and soil health. Depending on how they're managed, nitrogen and carbon can also be significant sources of emissions.

As nitrogen cycles through the environment, some of it will be released as nitrous oxide. As carbon cycles through the environment, it can become either methane or carbon dioxide.

Nitrous oxide can be produced directly from decomposing manure – in storage and on the field. It can also be produced indirectly. Large amounts of N are lost as ammonia gas when manure is exposed to the air, either on the barn floor or in the field. Part of this ammonia can be converted to N_2O. Indirect losses also result from runoff to surface and ground water systems.

Wet, stacked solid manure is a source of nitrous oxides.

N_2O is produced in cropland soils as well. Denitrification – the conversion of plant-available nitrogen to nitrogen gases (including N_2O) – is caused by soil microbes in moist soils. Limiting excess available nitrogen in soils at any time is a key factor in limiting denitrification.

The rate of N_2O production from manure depends on storage system, temperature and manure type. The highest rates of nitrous oxide from manure come from a wet manure stack, with a large proportion of bedding, piled outdoors in warm weather.

The rate and extent of denitrification from soil depends on the concentration of oxygen in the soil. In stored manure, the rate and extent are determined by the amount of plant-available N and the amount of carbon.

When manure N is applied, it has two forms: organic N and inorganic N (NH_4^+). The organic N fraction is mineralized to form ammonium (NH_4^+), which can be used by the plant or nitrified. (Nitrification can also be a source of N_2O.)

Nitrified N (NO_3^-) can be used by a crop or soil microbes, or lost from the system through leaching or runoff as NO_3^-. This nitrate can enter ground or surface water, directly or indirectly, only to be denitrified to nitrous oxide or nitrogen gas.

N_2O fluxes are sporadic. Much of the nitrous oxide from cropland and manure piles comes from thawing conditions of late winter and early spring.

In warm weather, nitrates in wet topsoil will emit nitrous oxides.

AMMONIA (NH_3) GENERATION

Agriculture, especially livestock, is a significant source of ammonia (NH_3):

- livestock is the source of 81%
- fertilizers account for 19%.

Ammonia is reactive in the atmosphere:

$NH_3 + H_2O = NH_4^+ + OH^-$ (hydroxide)

NH_3 can be added to any moist surface or surface water (in acidic conditions) to form ammonium. In both soils and water, dissolved ammonium can be nitrified (i.e. changed to nitrate or NO_3^-) and then denitrified (source of greenhouse gas, N_2O).

In pig farms, up to 95% of the ammonia can be lost before reaching the field. Up to 40% can be lost in liquid storages.

THE KYOTO PROTOCOL

In December 1997, more than 160 countries negotiated binding limitations on greenhouse gases for the advanced industrialized nations. The outcome of the meeting was the Kyoto Protocol, which sets targets to reduce greenhouse gas emissions by at least 6.0% before 2012. It also describes several options available for signatories to meet the targets.

To meet the Kyoto Protocol, over 80% of the feasible potential improvements (at 10% adoption rates) are possible by the year 2010 in the livestock and poultry sector alone, according to climate change studies conducted by Agriculture and Agri-Food Canada.

Approximately 50% of the reductions could come from the adoption of BMPs for comprehensive manure and nutrient management, due to reduced methane and nitrous oxide emissions – as opposed to carbon sinks in cropland and forest conditions.

The sooner action is taken, the sooner positive impact will be realized. Waiting too long may make any action inconsequential!

BMP OPPORTUNITIES – AN OVERVIEW

Some BMPs reduce GHGs, but may contradict soil and water conservation practices.

As we've noted, practical improvements to production, nutrition, product quality and safety, waste management, crop production and water protection translate into greenhouse gas reductions.

In terms of inputs, livestock sources of greenhouse gas are usually the result of production and nutrient inefficiencies. Small changes can have significant effects, as well as improve production, save money, and benefit water quality.

In terms of outputs, manure and other waste management BMPs – whether as is or fine-tuned – will lower greenhouse gas levels.

To get us started, here's a brief match-up of gases with practices.

GHG	TO REDUCE EMISSIONS	TO REDUCE ATMOSPHERIC LEVELS
METHANE CH_4	✔ improve rumen fermentation efficiency ✔ improve manure management ✔ generate biogas from manure and other materials ✔ improve soil quality and drain wet cropland	✔ improve soil quality to fix methane ✔ keep natural areas such as wetlands and woodlands
NITROUS OXIDE N_2O	✔ improve livestock nutritional balance ✔ reduce anaerobic conditions in solid manure ✔ improve nutrient use efficiency (NUE) for nitrogen	
CARBON DIOXIDE CO_2	✔ improve livestock production efficiency and health ✔ reduce soil quality degradation – with less tillage ✔ conserve energy on the farm	✔ increase soil organic matter levels ✔ increase acres of forage, trees and shrubs, other perennials

An experimental vaccine exists that reduces methane emissions from ruminants.

To reduce energy use in your operation, begin by conducting an energy audit. Also investigate the suitability of alternatives for your operation.

REDUCING METHANE (CH_4) EMISSIONS FROM LIVESTOCK AND POULTRY PRODUCTION SYSTEMS

GHG-BMPs	IMPACT
IMPROVE PRODUCTION EFFICIENCY	• increases production per unit of greenhouse gas emitted • lowers methane emissions from ruminants (belching) • reduces manure volume with improved efficiency ➧ lowers emissions
IMPROVE LIVESTOCK NUTRITION	• improves nutrient utilization • lowers methane emissions from ruminants (belching) • reduces manure volume with improved efficiency ➧ lowers emissions  **Fine-tune ruminant nutrition to reduce methane.**
USE FEED ADDITIVES TO IMPROVE NUTRIENT EFFICIENCY	• lowers methane emissions from ruminants (belching) • reduces manure volume with improved efficiency ➧ lower emissions
CHOOSE THE MOST EFFECTIVE TYPE OF MANURE STORAGE (SOLID, LIQUID)	• lowers methane emissions when manure is stored at lower temperatures and with better aeration
DIVERT RUNOFF AND WASHWATERS	• lowers emissions because less liquid means less anaerobic conditions
REMOVE MANURE FREQUENTLY	• reduces methane emissions by reducing unnecessary anaerobic conditions in bedded yards and housing
COVER MANURE STORAGE	• lowers methane emissions from manure stored at lower temperatures
USE ADDITIVES TO MANURE TO REDUCE EMISSIONS	• lowers methane emissions with the inhibition of methanogenesis (microbial methane production in anaerobic conditions)
USE BIOGAS AS A FUEL SOURCE WITH ANAEROBIC (METHANE) DIGESTION	• eliminates methane emissions in closed system where methane is captured and used for electrical energy production  **Convert a large liquid manure storage to an energy-generating anaerobic digestion system.**
DON'T BURN GARBAGE	• eliminates methane emissions
IMPROVE SOIL DRAINAGE	• lowers methane emissions by reducing anaerobic conditions in soil

REDUCING NITROUS OXIDE (N_2O) EMISSIONS

GHG-BMPs	IMPACT	
REDUCE N CONTENT IN MANURE AND URINE ✔ improve feed efficiency ✔ improve nutrient balance ✔ improve amino acid balance ✔ reduce crude protein	• reduces ammonia emissions – which can convert to nitrous oxide when returned to soil • reduces nitrous oxide emissions from stored and applied manure	 **Improve nitrogen nutrition and feed practices in all livestock to reduce nitrous oxide emissions.**
REDUCE ANAEROBIC CONDITIONS IN SOLID MANURE ✔ improve ventilation ✔ keep facilities clean ✔ change bedding frequently ✔ keep stored manure dry	• reduces ammonia emissions – which can convert to nitrous oxide when returned to soil • reduces partial anaerobic conditions and nitrous oxide emissions from solid manure • reduces methane emissions as well	 **Reducing anaerobic conditions in manure reduces methane from liquid manure and nitrous oxide from solid manure.**
REDUCE N-LOSSES WHEN APPLYING MANURE ✔ don't apply in wet conditions ✔ don't apply in fall and winter ✔ incorporate manure ✔ don't leave manure on surface in reduced tillage systems	• reduces ammonia emissions – which can convert to nitrous oxide when returned to soil • reduces nitrous oxide emissions from soil and applied manure (by reducing denitrification) • makes more N available to growing crop	
IMPROVE NUTRIENT USE EFFICIENCY (NUE) FOR NITROGEN ✔ test soils for all nutrients ✔ account for organic N-sources ✔ apply what a crop needs – when needed ✔ don't apply fertilizer N if wet ✔ don't apply urea fertilizer if dry ✔ use catch crops and other cover crops	• reduces nitrate levels in soil during the off-season • reduces nitrous oxide emissions from soil and applied manure (by reducing denitrification) • makes more N available to growing crop	 **NUE means making better use of soil-based and added crop nutrients.**
IMPROVE SOIL AERATION AND QUALITY ✔ drain wet cropland soils ✔ increase soil carbon levels ✔ reduce tillage ✔ reduce erosion and runoff ✔ rotate with forages – hay and pasture	• reduces nitrate levels in soil during the off-season • reduces nitrous oxide emissions from soil and applied manure (by reducing denitrification) • makes more N available to growing crop • reduces methane emissions as well	 **Improve soil physical conditions with improved tillage and subsurface drainage systems.**

REDUCING CARBON DIOXIDE (CO_2) EMISSIONS AND INCREASING SEQUESTRATION

GHG-BMPs	IMPACT	
REDUCE SOIL ORGANIC CARBON LOSS ✔ reduce tillage ✔ establish erosion control structures and practices ✔ water table management in organic soils	• soils are disturbed less – so less organic carbon is converted to carbon dioxide	 **Conserve soil – reduce tillage to save energy and soil carbon levels.**
INCREASE SOIL ORGANIC CARBON LEVELS WITH PLANT MATERIALS ✔ rotate crops with forages and ploughdowns ✔ grow cover crops ✔ improve pasture lands ✔ increase soil cover with crop residues ✔ grow crops that return large amounts of biomass (corn, sorghum, rye, etc.)	• live plant material (carbon) is converted to soil organic matter (sequestered) • root biomass is converted to soil organic carbon • dead plant material (crop residue) adds to soil organic carbon levels when left on surface	 **Reintroduce forages into your operation – forages as hay or pasture sequester carbon, reduce methane loss, and improve NUE for nitrogen.**
INCREASE SOIL ORGANIC CARBON BY ADDING ORGANIC NUTRIENTS ✔ add solid or liquid manure ✔ add composts ✔ add biosolids	• organic sources of nutrients contain organic matter as well as nutrients – this is converted to soil • organic carbon	
INCREASE SOIL ORGANIC CARBON BY CONVERTING CROPLAND ✔ to pasture ✔ to permaculture crops – orchard, vineyards, nut trees, Christmas trees ✔ to wildlife habitat – grasses, trees, shrubs, wetlands ✔ to forest land – trees as crops	• soils are undisturbed – very little organic carbon is converted to carbon dioxide • soil organic C levels build up to near-natural conditions	 **Look for opportunities for planting trees to sequester carbon and beautify and add value to your property at the same time.**

LIVESTOCK PRODUCTION SYSTEMS AND PLANNED CHANGE

Most livestock production systems aim to produce high quality products efficiently and profitably. There are three broad classifications.

LIVESTOCK PRODUCTION SYSTEM	DESCRIPTION	GHG OPPORTUNITIES
GRAZING SYSTEMS	• almost exclusively pasture and grazing systems	• improved pasture • intensive grazing management • energy conservation • protection of natural areas from grazing livestock
MIXED SYSTEMS	• may include grazing • most feeds are grown on-farm • livestock and crop production systems are highly interrelated (e.g., manure used on farm)	• genetic improvements for production • improved nutrition and feeding • improved ventilation • energy audit of livestock facilities • removal of manure to storage • nutrient use efficiency • crop rotation and cover crops • intensive grazing management • management of natural areas
INTENSIVE SYSTEMS	• most feed is grown in another operation or is purchased from feed industry • some or all of the manure is exported to other cropland or for other uses (e.g., compost, growth substrates, feeds)	• genetic improvements for production • improved nutrition and feeding • improved ventilation • energy audit of livestock facilities • green energy production • reduced nutrient loss from application • protection of natural areas

For the most part, BMPs that focus on atmospheric and other environmental improvements share farmers' goals of improved efficiencies and reduced waste.

COMPONENTS OF A LIVESTOCK PRODUCTION SYSTEM

Every livestock production system (LPS) includes these key components:

- ▸ **infrastructure** – housing, system design, fields, topography
- ▸ **production and quality control management practices** – breed, handling system, genetics, nutrition, grazing management, health and quality control
- ▸ **nutrient and natural resource management** – manure storage, handling and application, crop management
- ▸ **marketing and business management** – markets, financing, etc.

Naturally, the relative importance of each component varies with each issue. For example, the food quality and safety component would rank higher in a discussion about the production and marketing of livestock products.

OPPORTUNITIES

For the purpose of presenting **opportunities** for greenhouse gas BMPs, we've categorized LPSs for beef, dairy, swine, sheep and poultry in the following ways:

- **genetics and breeding** – improvements in production, reproduction and feed conversion
- **nutrition and feeding** – reducing, modifying, supplementing and targeting diets and feeding practices to improve use efficiency and reduce inputs
- **other LPS components** – the combination of animal handling practices, food quality and safety and animal care to reduce stress and increase efficiency
- **housing and environment** – livestock housing, bedding selection, layout, interior climate control, and ventilation to promote health and reduce emissions
- **energy** – the impact of conserving energy in an LPS and the opportunities to produce energy on-farm
- **manure management** – manure and other waste collection, transfer, storage and handling systems to reduce emissions
- **nutrient management** – manure transfer, application and environmental protection measures
- **cropland management** – BMPs protecting soil and water plus practices to reduce nutrient loss
- **pasture and grazing management** – techniques that improve production and reduce emissions
- **natural areas management** – protection of natural areas (wetlands, watercourses) and other areas with permanent vegetation (windbreaks, buffer strips, woodlots).

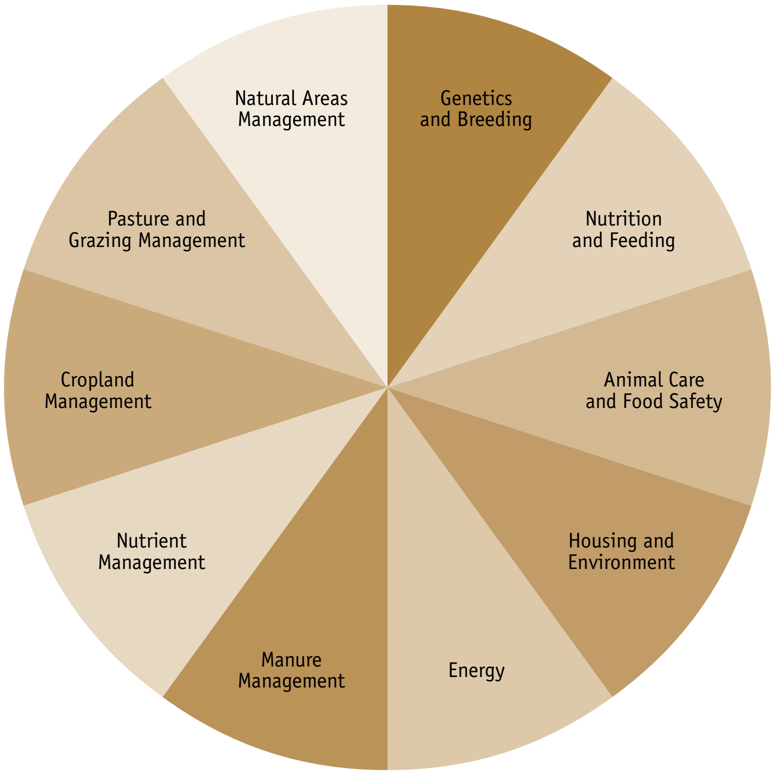
We'll explore all these areas in the following chapter.

Genetic improvements have led to marked improvements in reproductive and production efficiencies – particularly in the poultry sector.

Ventilation will reduce humidity and the moisture content of bedding and manure. Dry bedding and manure emit less methane, nitrous oxide and ammonia.

Dry manure emits fewer greenhouse gases.

OPPORTUNITIES FOR GHG REDUCTION IN LIVESTOCK PRODUCTION SYSTEMS



Changes to one component usually require changes to at least one other component. Implementing BMPs for emission reductions is no different. Plan in accordance with a systems approach.

PLANNING CHANGES AND PREDICTING IMPACT ON YOUR SYSTEM

Incorporating measures for emission reductions works best with an interactive systems approach. In other words, the impact of each modification (e.g., reduction in crude protein in diet to reduce nitrous oxide emission) on the other parts of the system (e.g., alternative nutrient management strategies, application method and timing) is identified and everything is adjusted accordingly.

Those who try to make substantial changes to their operation without regard to the systems approach risk failure.

Here's an example of how practices that lead to reduced methane in a beef manure handling system can have implications for other components.

✔ Sample BMP: **Meet minimum requirements for effective fibre with the use of high-quality forage feeding.**

possible consequences:

▶ less manure volume generated means more space in solid **manure storage**

▶ more storage capacity could mean more room for scrapings from more frequent yard maintenance **(handling)** and less methane from wet, manured yards and lots

▶ improved storage capacity could impact **nutrient management** (timing/application) by increasing the number of application options

✔ Sample BMP: **Clean lot and yard frequently to promote aerobic conditions.**

possible consequence:

▶ herd remains off pasture **(grazing management)** until conditions are less damage-prone (wet soils, compaction)

Well-maintained yards generate less greenhouse gas than those cleaned infrequently.

Less fibre will generate less manure, which leads to more effective storage space and better application opportunities.

Improved storage in semi-confined operations facilitates more frequent yard cleaning and delayed grazing until pasture conditions are drier and less prone to compaction.

GENETICS AND BREEDING

Improvements in reproductive efficiency translate directly to decreases in emissions from livestock operations.

As a producer, you work to better your breeding stock for many reasons, including improved production, product quality and disease resistance.

Genetic improvement programs are in place for all common livestock and poultry species, offering increased output from lower input costs. Improved genetics can also reduce greenhouse gas production from livestock operations. An inefficient livestock operation, for example, requires more units of livestock to produce the equivalent output of an efficient operation. As you improve production efficiency, you significantly reduce greenhouse gas emissions.

Increasing **feed efficiency** in cattle can do double duty too, by increasing productivity and reducing greenhouse gas emissions. Scientists are developing new selection tools to increase feed efficiency in cattle through breeding. Innovative methods to easily identify cattle that are genetically superior for feed conversion are becoming available to producers.

Production efficiency can also be genetically improved by breeding for increased **reproductive efficiency**. For example, the number of offspring per sow can be increased through higher pre-weaning survival and lower mortality. Fewer greenhouse gases are produced per unit of output when reproductive efficiency improves.

Many other livestock species have been improved through genetic selection of **growth rate**. Studies have shown that genetically increasing the growth rate will increase the amount of output per unit input, resulting in animals that reach market faster, consume less feed, and more efficiently use fixed resources.

The environmental benefits from increased growth rate in all species are tremendous. More livestock products are produced per unit of greenhouse gas emission. Canadian farmers can increase production of livestock products without increasing the amount of land under cultivation.

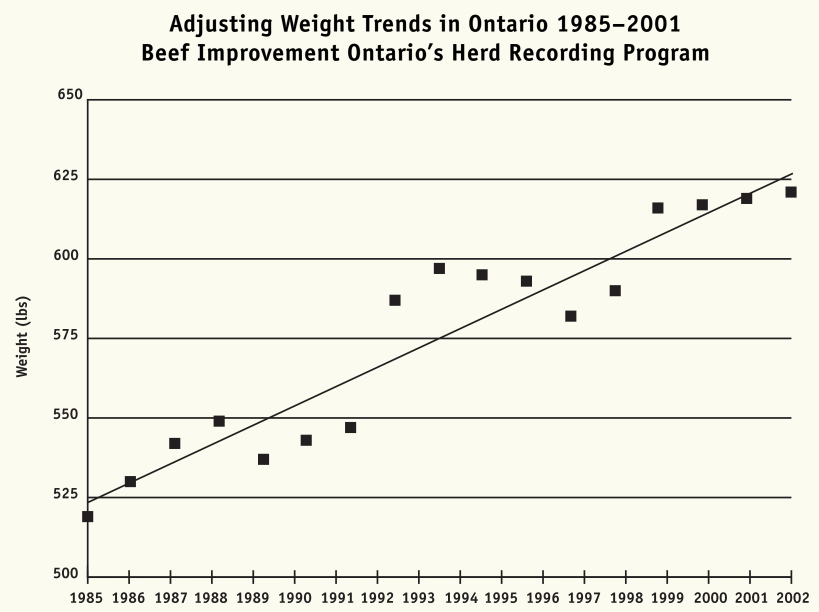
Broiler chicken producers have made great improvements to the productivity and efficiency of broiler birds. Annual rate of genetic improvement for growth rate is about 2.4%, while feed efficiency improves 1.2% per year. This has translated into days-to-market being cut by 50%, and continued improvements are anticipated.

The broiler industry has made great improvements in production efficiency. In so doing, they've also reduced net emissions of greenhouse gases per unit of production.

KEY BMPS

✔ **Select breeding specimens for improved or above-average reproductive efficiency.** Keep accurate records of birth numbers, weights, survival and early development.

✔ **Implement a genetic improvement program or source genetically improved livestock for your farm operation.** Benefits: increased productivity, increased output, and increased profit. Greenhouse gas emissions will also decrease due to better utilization of feed, less manure, and reduced time to market.



Genetic improvement has already contributed to lower greenhouse gas production on Ontario farms. Livestock producers have been using genetic selection for growth traits for many years. Results from Beef Improvement Ontario's herd management program shows the average calf weaning weight has increased from 543 lbs in 1990 to 621 lbs in 2001. According to the Canadian Cattlemen's Association's Greenhouse Gas Calculator, this translates to a greenhouse gas reduction of 12.5%, holding other variables constant. And there is potential to increase this benefit in coming years.

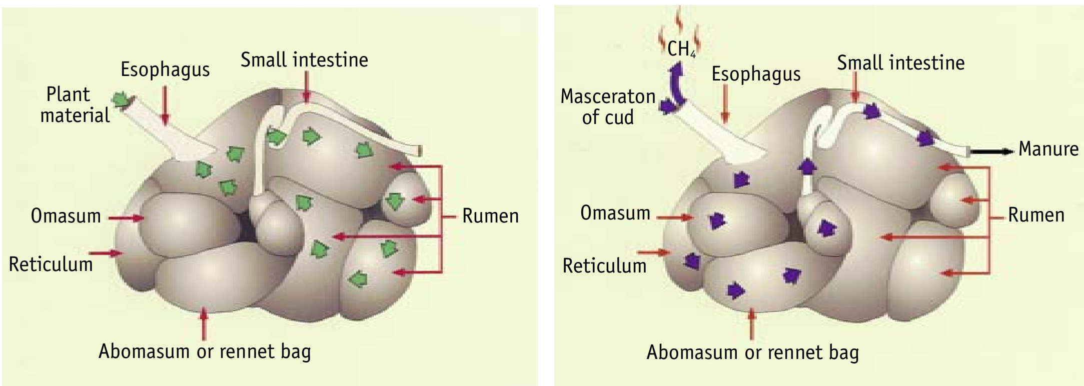
NUTRITION AND WATER

Less waste and improved feed conversion to marketable livestock product means lower emissions per animal from the cattle industry.

Diet and feeding strategies are of critical importance to livestock and poultry health, performance and product quality. Reduced feed wastage and improved performance can be attained with careful attention to the principles of animal nutrition, feed analysis, ration formulation and feeding strategy.

Animal digestion and excreted feces/urine are the main sources of greenhouse gases and potential water pollutants from livestock agriculture. Obviously, practices that improve performance and reduce nutrient wastes will help reduce emissions.

PRINCIPLES



Ruminant livestock convert fibrous plant materials into food, thanks to a four-part stomach that includes the rumen, reticulum, omasum and abomasum. The rumen accounts for 80% of the total stomach volume. The rumen's function is to house microbes that break down and ferment the plant material into energy. Energy compounds are used for maintenance and production functions. Methane is a by-product of this process.

Technology that reduces feed loss translates to lower manure volumes and lower emissions.

The prime sources of greenhouse gases from livestock are rumen-sourced methane, methane from stored manure, and nitrous oxides and ammonia from manure. The nature and extent of these emissions relate directly or indirectly to animal nutrition.

Methane emissions from ruminants and non-ruminants can be reduced with better nutrition management – improving roughage quality and balancing with grains.

Meeting the requirements for essential amino acids can reduce nitrogen excretion. Use rumen-undegradable protein supplements such as roasted soybeans or corn gluten meal to minimize excesses of non-essential amino acids.

As you consider diet changes to reduce greenhouse gas emissions, re-orient yourself to the principles of nutrients and feeds. Start by analyzing your current feed materials. Whenever practical, seek assistance from a livestock nutritionist or feed company representative. They can help to formulate rations with available feeds – and supplements where necessary – to meet nutrition requirements, as well as to reduce emissions and meet production goals for your livestock or poultry operation.

For further information regarding the nutritional requirements of swine, beef, dairy, sheep and poultry, visit: www.nap.edu/browse.html

4 STEPS TO PRODUCTIVITY, REDUCED NUTRIENT WASTE, AND REDUCED GREENHOUSE GAS EMISSIONS

1. Determine animals' requirements. Match feed to nutritional requirements and waste less feed.
2. Evaluate feeds. Test feedstuffs so that you know nutrient levels fed. This can help reduce nutrient levels in excreted wastes.
3. Feed only what they need. By meeting needs, you improve efficiency and waste less.
4. Manage nutrient waste and manure. Manage manure materials so that feed crops can use manure nutrients efficiently.

DIGESTION

Digestion is a complex metabolic process. Digested feed is used for:

- maintenance – respiration, normal biological processes
- growth and production requirements – meat, eggs, milk
- reproduction.

Nutritional requirements are directly related to growth stage and type of production.

Excretion rates are also related to nutrient availability. Excretion is related to:

- feed and nutrients consumed
- efficiency of uptake
- normal metabolic excretions (e.g., tissue breakdown).

Properly formulated diets that precisely meet requirements for maximum efficient growth will also reduce excessive N and P excretion.

Better nutrition means that more of the feed is assimilated for production and proportionally less is used for maintenance.

Evaluate feeds. Test feedstuffs so that you know nutrient levels being fed. This can help reduce nutrient levels in excreted wastes.

Monogastric (non-ruminant) animals, such as poultry, pigs, dogs and humans, are not able to digest cellulose efficiently.

Methane is a by-product of enteric digestion by microbes called methanogens. Methane is released mostly by belching. It represents a loss of dietary energy and feed inefficiency. CH_4 is proportional to feed components: high fibre = high methane.

Feeding a high-fibre diet leads to higher rates of methane generation.

Microbial digestion of fibres from roughages (cellulose) and starch (from grains) results in the production of energy for the animal. Rumen microbe species are specialized in their ability to break down either starch or cellulose. When the diet is high in roughages, the fibre-digesting microbes multiply and dominate. In a high-grain diet, the number of starch-digesting microbes increases.

Changes in the composition of a ration should be made gradually to allow time (about two weeks) for the rumen microbe population to adapt. Any practices that speed up the rate of passage of roughage through the digestive system will reduce the rate of enteric fermentation.

DIGESTION IN RUMINANTS

Ruminants generate 80% of the methane from livestock agriculture. They convert fibrous plant materials into food, thanks to a four-part stomach that includes the rumen, reticulum, omasum and abomasum. The rumen accounts for 80% of the total stomach volume.

The rumen's function is to house microbes such as bacteria, protozoa and fungi. These microbes break down and ferment the plant material into energy. Energy compounds are used for maintenance and production functions.

Ruminants can utilize two types of nitrogen compounds in their diet: true protein and non-protein nitrogen (npN). The digestion of a particular protein depends to a large extent on its degradability.

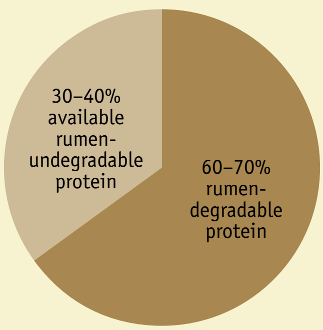
Non-protein N (e.g., urea, ammonium) is soluble and easily used by rumen microbes, as are some readily digestible proteins. The amount assimilated relates to the energy intake – much like the C:N ratio found in soils. If there is insufficient energy or excess protein, most of the npN will be excreted as urine.

Eventually the microbes become a source of protein as they pass into the small intestine.

N-use efficiency is related to two factors:

- ▶ the balance of protein types and N-sources fed, and
- ▶ the balance of N-sources and energy "fed" to the rumen bacteria.

Optimum diets usually contain 30–40% available rumen-undegradable protein and 60–70% rumen-degradable protein. Less than 30% of total protein should be in the form of npN.



Optimum diets usually contain 30–40% available rumen-undegradable protein and 60–70% rumen-degradable protein.

FEEDING MANAGEMENT FACTORS

FACTOR	DESCRIPTIONS
GROUPING	• Group animals for feeding by stage, age, weights
GENDER	• Group animals by sex for non-ruminants
ENVIRONMENT	• Change the diet to meet requirements as affected by season, local weather conditions, housing conditions
FEEDING STRATEGY	• Plan and adjust diets by growth stages (phase-feeding)
WASTE	• Use BMPs to reduce wastage and spillage
FEED PROCESSING	• Modify feedstuffs to make them more palatable and the nutrients more available

Group animals by growth stage, age, and weight to improve efficiency and reduce emissions.

FACTOR	DESCRIPTIONS
NUTRIENT CONTENT AVAILABILITY	• Use feed analysis results to determine availability and to formulate diets
GENETICS	• Adjust diet for genetic potential for growth rates, feed-conversion, etc.
FEED EFFICIENCY	• Adjust balances and use promoters to improve intake efficiency
SPECIAL FEEDS	• Use special amino acid feeds, feeds with specific enzymes
WATER SUPPLIES	• Ensure proper quality, safety and mineral content

NUTRITIONAL BALANCE AND EXCRETION

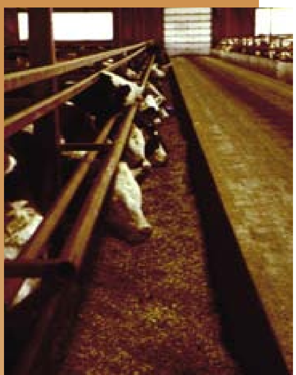
A properly formulated ration supplies adequate amounts of all nutrients to allow animals to achieve a desired level of production. Accurate ration formulation requires:

- allowance for animal characteristics – sex, weight, frame size, body condition, desired rate of gain, stage of production
- feed analysis
- consideration of other feeding management practices, e.g., feed additives.

Precision nutrition is a means of ensuring that livestock and poultry are fed the right quantity of nutrients in an ideal ratio to maintain optimum efficiency.

The ratio of amino acids AAs required for growth is fixed – a deficiency in one amino acid will affect the overall growth of all AAs.

AAs that are absorbed and not used for growth and production are used as an energy source. As a consequence, ammonia is produced. The ammonia is detoxified in the liver to produce urea, which is excreted in urine. Urea can volatilize (as ammonia) when mixed with feces.



Lacombe Research Centre estimates a 14% reduction in GHG emissions from feedlot cattle with properly balanced rations.

NUTRITION AND METHANE REDUCTION

Methane production by ruminants is a function of:

- feed characteristics
- feeding portions and schedule
- nutritional balance, e.g., high N in manure = more methane loss
- additives, and
- health and fitness of animal.

Dairy cattle methane emissions have dropped by 15% over 30 years, largely due to improvements in nutrition and production efficiencies. There are now 41% fewer dairy cows. Today's cows produce more milk per cow and 20% more milk overall.

DIET MANIPULATION BMPs

- ✔ **Determine nutrient content** to understand the bioavailability.
- ✔ **Adjust diets to ensure nutrient balance,** less nutrient waste and better performance (e.g., amino acid balance for methane reduction in swine).
- ✔ **Select feed materials for improved production.** Consider type, bioavailability and quality. In ruminants, high-quality forage consumption leads to less methane production; more grains, with less roughage and more available nutrients, lead to less methane.
- ✔ **Use speciality feeds.** Feeds with special ingredients can help improve feed efficiency (e.g., legumes with enzymes for non-ruminants).
- ✔ **Use additives where useful.** Copper and zinc balance can act as growth promotants for increased productivity.

Analyze feeds to determine bioavailability of nutrients.

Use high quality feeds. High quality forages will reduce methane emissions.

FEEDING MANAGEMENT BMPs

✔ **Group by sex, age and stage of production** to help target feeding to diet requirements (split-sex feeding).

✔ **Consider how feeds are processed.** Ground or pelleted feed can reduce methane by 20–40%.

✔ **Ensure proper feeder design and presentation.** These can reduce losses during feeding and wasted feed.

✔ **Adjust feeding to weather conditions.** Weather conditions can impact feeding programs. For example, under hot summer conditions, pigs eat less but require more energy for heat dissipation, requiring a nutrient-dense diet with a lower protein-to-energy ratio.

Reduce feed losses with improved technology.

Adjust feeding to weather conditions to reduce manure nitrogen content.

High digestibility of ingredients via technological treatments (particle size reduction, pelletting, expanding) or through the addition of enzymes can reduce excess wastes and nutrient losses. For example, with pelletization, feed efficiency has improved by 8.5% and protein digestibility by 3.7%.

Improving feed efficiency will reduce nutrient excretion.

NUTRITION AND REDUCTION OF NITROUS OXIDE FROM LIVESTOCK MANURE BMPs

✔ **Reduce crude protein in diets.** All nutrients should be balanced. For ruminants, high N diets = great loss of N in urine. For example, researchers have documented 80% of N loss when consumption of N for swine exceeds 500 g/day. Urinary N excretion increases exponentially to N intake.

✔ **Reduce crude protein in ruminant diets.** Nitrogen plus high crude protein = high N excretion in dairy cattle.

- ✔ **Provide a better AA balance.** In swine, this could make for 40% less methane and ammonia (N). In poultry, with a 40% adoption rate, a 15% reduction in the protein intake by poultry would help meet Kyoto protocols.
- ✔ **Improve performance potential.** Improving productivity and feed efficiency is the most obvious strategy for reducing nutrient excretion and increasing profitability.
- ✔ **Enhance nutrient availability.** Treat feeds for non-ruminants with enzymes and eliminate anti-nutritional factors from feed materials (e.g, tannins, polyphenols).
- ✔ **Practise phase feeding.** Different diets can be fed so as to more closely match the nutrient requirements of the separate sexes while limiting excesses and reducing excretion. For grower-finisher pigs, this will help balance AAs in the diet to the requirements of the animal so less N is excreted. Meeting the N needs more precisely would reduce N in manure by 13%.
- ✔ **Use supplemental AAs to produce a protein with a near-perfect AA balance.** A 15-kg pig can convert 87% of its absorbed nitrogen above maintenance to carcass protein. For poultry, supplement methionine and lysine to reduce crude protein content. (AA levels depend on ratio of digestible lysine to other AAs.)
- ✔ **Follow feeding guidelines to reduce ammonia emissions.** Formulate rations that meet requirements and reduce ammonia emissions.

Reduce nitrogen levels in manure with better AA balances in rations.

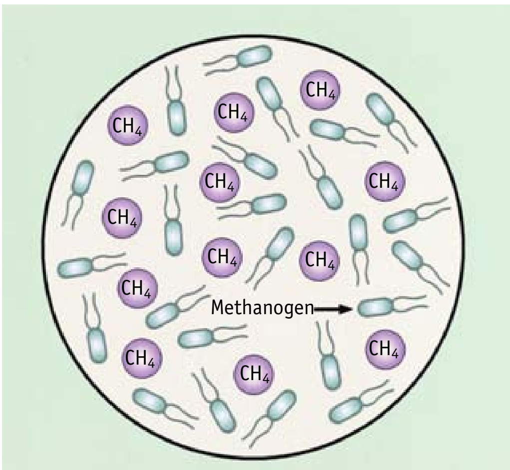
Practise phase-feeding to reduce excretion of nitrogen.

IONOPHORE SUPPLEMENTS

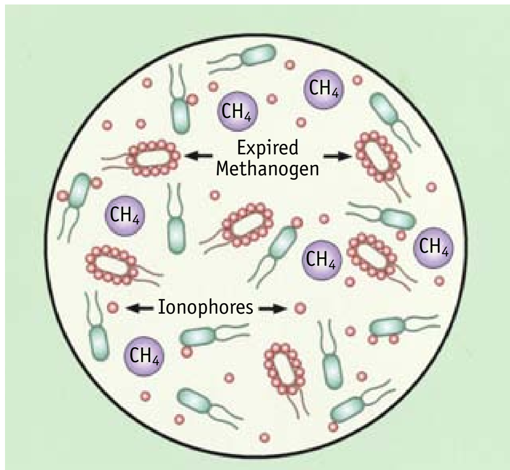
Ionophores reduce methane production from rumen fermentation and improve performance and gain. Use ionophores to:

- improve efficiency of energy metabolism by increasing the ratio of acetate to propionate (volatile fatty acids or VFAs) and decreasing energy lost during feed fermentation
- decrease breakdown of feed protein and bacterial protein synthesis, which makes high-roughage feeding more efficient
- reduce incidence of acidosis, coccidiosis and grain bloat.

Ionophores may reduce methane by up to 24%.



Ionophores reduce methane production from rumen fermentation.



Ionophores inhibit methanogenesis and can reduce methane emissions by up to 24%.

LIVESTOCK DRINKING WATER

Clean water in sufficient quantity is a necessity for animal health and production efficiency. Again, the link to greenhouse gas emission reduction is making your operation as efficient as possible. Limitations on water intake can affect performance through dehydration, sight and hearing impairment, and urinary problems. Factors that can affect water intake include these:

- water temperature – ideally 4.0–18.0°C (40–65°F)
- access – preferably free
- nutrients in diet – increases in salts or protein levels stimulates increased intake
- stress – can reduce consumption
- water quality – including but not limited to presence of salinity, dissolved solids, nitrates, pH, microbiologic properties, and other chemicals.

✔ **To protect water quality:**

- **get it tested regularly**
- **interpret results** to determine if there is an ongoing water safety or quality problem
- **take corrective measures** for well protection, repair, water treatment or well abandonment.

Nitrates, bacteria, organic materials and suspended solids are the most common substances that can contaminate on-farm water supplies, which in turn can adversely affect livestock and poultry.

Test drinking water quality regularly and take corrective measures if water test results indicate a water safety problem.

ANIMAL CARE AND FOOD SAFETY

ANIMAL HANDLING AND WELFARE

The link between greenhouse gas reduction and animal care and food safety is, once again, production efficiency. There are many resources available on these topics. We'll just touch on key points here.

Better handling means better care and less animal stress. It can also mean less damage to animal products, which translates into less waste, improved efficiency and lower greenhouse gas emissions.

Improvement in herd health status, or in the indoor housing environment to which animals are exposed, will lead to improvements in feed efficiency and thus reductions in nutrient excretion.

Health and animal care includes:

- **animal identification and record-keeping**
- **vaccinations**
- **a bio-security plan**
- **security and access.**

It's estimated that converting to a specific pathogen-free herd health status can improve feed efficiency by as much as 10% and, as a result, decrease N excretion by 10%.

Herd health is directly related to production and production efficiencies.

ON-FARM FOOD SAFETY

Most animal commodity groups have developed food quality and safety programs that promote specific good production practices (GPPs). In most cases, these quality and safety GPPs increase efficiency, reduce waste, and improve sanitation – all of which help reduce greenhouse gas emissions.

Chicken Farmers of Ontario:
On-Farm Food Safety Assurance Program
www.cfo.on.ca
905-637-0025

Dairy Farmers of Ontario:
Ontario Raw Milk Quality Program
www.milk.org
905-821-8970

Ontario Cattlemen's Association:
Quality Starts Here
www.qualitystartshere.on.ca
519-824-0334

Ontario Pork:
Canadian Quality Assurance Program
www.ontariopork.on.ca
1-877-ONT-PORK

Ontario Sheep Marketing Association
www.ontariosheep.org
519-836-0043

For more information, please refer to the Quality Assurance reference materials for your commodity group.

HOUSING

Proper ventilation design makes the animal environment, bedding and manure drier. Fewer greenhouse gases are emitted from dry manure.

Greenhouse gas emissions from livestock and poultry facilities can be reduced with proper siting, design, ventilation and bedding/manure management. Energy savings indirectly reduce emissions. Again, it's a win–win for you and the environment.

VENTILATION AND HEATING

✔ **Provide adequate ventilation to make bedding areas drier and cooler.** This can reduce methane and ammonia emissions. Basic, natural ventilation systems use sidewall openings or combinations of sidewall and ridge or stack openings. Their insulation is similar to mechanically ventilated barns, and must be able to respond to changes in winds (speed and direction) and air temperatures.

✔ **Manage ammonia levels through ventilation.** Ammonia is produced by the decomposition of the nitrogenous compounds (e.g., non-degraded proteins) in manure. High levels of ammonia (over 15 ppm), irritate the eyes, nose and throat.

Ammonia's characteristic strong odour makes it easily detectable as soon as levels reach 5–10 ppm. To control ammonia levels:

- ✔ **reduce moisture content** in manure and humidity in facility
- ✔ **increase ventilation rate** (may need additional heat to offset lower barn temperature)
- ✔ **increase aeration of pack manure and housing area** where and when possible (with the help of improved ventilation) – can reduce methane and N-oxide losses by 10%.

✔ **Use higher R-value insulation** to decrease conductive heat loss.

Increased ventilation will reduce ammonia levels in barns.

Research on feed additives, manure handling and proper management are underway to solve the ammonia problem. It's known that you can maintain acceptable levels of ammonia with proper manure management and adequate ventilation and heating in all livestock and poultry barns.

DESIGN AND BEDDING

For dairy

✔ **Choose bedding carefully.** Bedding is a key source of greenhouse gases. Straw contributes approximately 80% of the manure methane produced in tie-stall operations. Bedding is the largest source of N_2O, doubling the total greenhouse gas emissions from cattle.

✔ **If you're expanding your operation, consider free-stall.** Tie-stall operations with straw generate more methane than free-stall housing

✔ **Manage the system with less confinement.** The greater the confinement, the higher the emissions of methane and nitrous oxides.

Bedding is the largest source of nitrous oxides.

For beef

✔ **Manage the system with less confinement.** The more confinement, the higher the emissions of methane and nitrous oxides. Confined systems generate more greenhouse gas than pasture-based, as there is more opportunity for anaerobic and partially anaerobic conditions in yards and feedlots.

✔ **Manage the manure.** Frequent cleaning and removal to storage will reduce manure build-up and anaerobic conditions that produce methane and nitrous oxides.

For swine

✔ **Bedding is not better.** Bedding increases N_2O emissions by 10-fold over liquid systems with anaerobic conditions that generate methane.

Management-intensive grazing systems produce fewer emissions than confinement systems.

For poultry

✔ **If you're expanding – consider free range.** Free range produces less greenhouse gas than caged systems. The highest levels of N_2O come from caged systems.

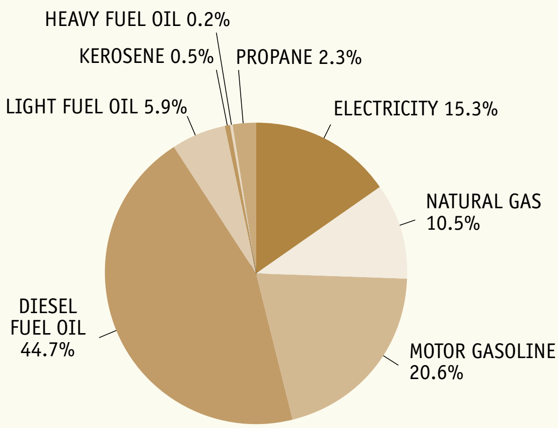
✔ **Increase ventilation with conveyor transfer and storage.** This will reduce moisture contents and emissions of nitrous oxides and, to a certain extent, methane.

Caged systems emit more nitrous oxides than free-range systems.

ENERGY CONSERVATION AND PRODUCTION

CONSERVATION

Agriculture is an energy-intensive industry. Crop production, livestock housing, transportation, and domestic life are just some of the vital activities that need reliable energy sources.



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ENERGY USE BY ENERGY SOURCE
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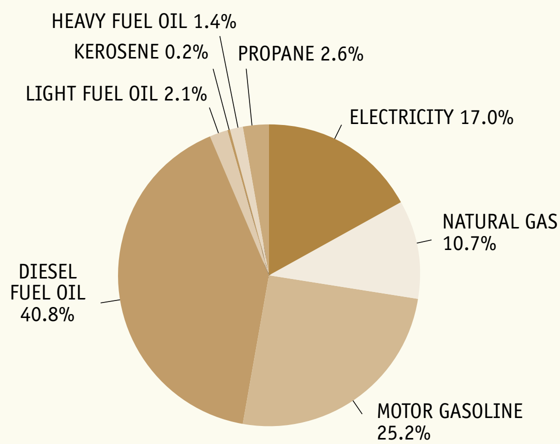

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Agriculture is an energy-intensive industry. A high proportion of energy used is for farm vehicles and equipment.

There are also some exciting energy production opportunities that we'll look at later in this section.

Taking advantage of the many opportunities to conserve energy is a win–win: lower your expenses <u>and</u> emissions.

HOME ENERGY CONSERVATION		
CATEGORY	**BEST MANAGEMENT PRACTICES**	**IMPACT**
SITING	✔ Site for east-west axis orientation ✔ Design roof overhangs to save energy	• Maximized solar energy capture in winter • Minimized solar energy effect in summer • Reduced heat loss • Reduced energy requirements
LANDSCAPING	✔ Use shade trees ✔ Site building for shelter ✔ Plant shelterbelts	• Maximized solar energy use • Protection from prevailing winds by using hills • Reduced heat loss/reduced energy needs
INSULATION	✔ Know where insulation is needed ✔ Choose suitable products ✔ Install insulation properly ✔ Install vapour barriers properly	• Insulated where heat loss is greatest • Reduced energy requirements • Ensured effectiveness of insulating materials • Reduced heat loss in winter • All key areas of heat loss are insulated
VENTILATION	✔ Follow building codes ✔ Use suitable technology	• Protected insulation and vapour barrier • Reduced energy requirements
HEATING	✔ Properly size system to meet needs ✔ Choose high efficiency furnace ✔ Use supplemental heating	• Improved energy efficiency/reduced energy requirements
HOME ENERGY AUDITS	✔ Perform an energy audit on your home	• Improved energy efficiency/reduced energy requirements
ENERGY EFFICIENCY	✔ Use natural lighting ✔ Use open floor plans ✔ Close off less-used spaces ✔ Choose energy-efficient flooring and décor ✔ Use energy-efficient doors and window ✔ Use energy controls – for heating, lighting, appliances ✔ Use energy-efficient appliances ✔ Use energy-efficient lighting	• More effective use of natural energy sources • Improved comfort • Reduced hydro needs and energy requirements
	✔ Try passive energy conservation: • day-lighting • natural ventilation • cooling towers	• Improved comfort • Reduced heat loss in winter • Increased heat loss in summer • Reduced energy requirements
	✔ Incorporate renewable energy whenever possible – photo-voltaics, solar, smallwind, geo-thermal, etc.	• Reduced hydro needs and energy requirements

LIVESTOCK FACILITIES

CATEGORY	BEST MANAGEMENT PRACTICES	IMPACT
SITE SELECTION	✔ Plan facilities for east-west axis orientation ✔ Place close to other buildings and hills ✔ Plant shelterbelts ✔ Design roof overhangs to save energy	• Maximized solar energy capture in winter • Minimized solar energy effect in summer • Reduced hydro needs and energy requirements geo-thermal, etc.
INSULATION	✔ Know where insulation is needed ✔ Choose suitable products ✔ Install insulation properly	• Reduced hydro needs and energy requirements
VENTILATION	✔ Select suitable technology ✔ Use energy-efficient systems (e.g., heat-recovery)	• Improved livestock comfort • Direct reduction of greenhouse gas • Reduced energy requirements
PASSIVE ENERGY SYSTEMS	✔ Use passive energy heat-recovery systems to release energy during cold nights	• Reduced heat loss • Reduced energy requirements
ELECTRICAL MOTORS	✔ Use energy-efficient motors ✔ Monitor energy use ✔ Properly size wire, and back-up electrical source	• Improved management of loads and peaks • Reduced demand-side electrical use
FARM ENERGY AUDITS	✔ Do an energy audit for your operation	• Improved energy efficiency • Cost savings

Use energy-efficient ventilation systems.

DAIRY		
CATEGORY	**BEST MANAGEMENT PRACTICES**	**IMPACT**
ENERGY-EFFICIENT SUPPLEMENTAL	✔ Install energy-efficient fluorescents in stanchion/ tie-stall barns ✔ Install high-intensity discharge (HID) lamps	• Increased production • Reduced hydro requirements and demands
COW COMFORT	✔ Install sprinklers ✔ Install evaporative cooling pads	• Increased cooling • Improved energy use
MILKING EQUIPMENT	✔ Use variable-speed drive equipment ✔ Use milking precoolers ✔ Install water heating and heat reclaimer ✔ Maintain vacuum systems ✔ Use scroll compressors	• Improved energy efficiency • Cost savings • Reduced energy requirements
NUTRIENT MANAGEMENT	✔ Complete and follow a nutrient management plan	• Reduced energy from reduced fertilizer use • More efficient use of manure application equipment

Solar power can be used to provide drinking water to livestock.

OTHER LIVESTOCK ENERGY SAVINGS		
CATEGORY	**BEST MANAGEMENT PRACTICES**	**IMPACT**
SAVE HEAT IN HOG OPERATIONS	✔ Use hovers (solid partition enclosures located in farrowing pen, accessible to piglets) ✔ Monitor and reduce energy use	• Reduced fossil fuel consumption • Increased electrical energy savings
OTHER ENERGY SAVINGS IN HOG BARNS	✔ Use energy-efficient lighting ✔ Improve ventilation ✔ Improve cooling ✔ Install heat exchangers ✔ Use evaporative pads for summer cooling	• Reduced electrical demand and energy consumption • Reduced heat-energy use • Increased comfort – less mortality
ENERGY EFFICIENCY FOR POULTRY	✔ Use energy-efficient lighting ✔ Improve ventilation ✔ Improve heating efficiency	• Reduced electrical demand and energy consumption • Reduced heat-energy use • Increased comfort – less mortality
GRAZING LIVESTOCK	✔ Alternate water sources using solar and wind power	• Reduced electrical energy use
GRAIN DRYING	✔ Use alternative energy sources ✔ Install heat reclamation systems ✔ Integrate natural drying ✔ Use aeration treatments to improve efficiency	• Reduced fossil fuel consumption and electrical energy savings

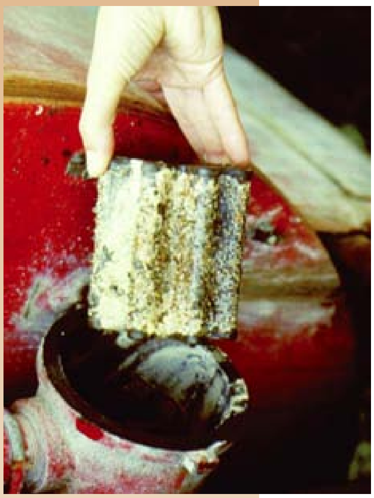
ENERGY CONSERVATION IN FIELD OPERATIONS

CATEGORY	BEST MANAGEMENT PRACTICES	IMPACT
FUEL CONSUMPTION	✔ Assess fuel use ratings of new farm equipment ✔ Use fuel alternatives, e.g., propane, biofuels	• Reduced fossil fuel consumption • Reduced direct GHG emissions
TRACTOR TIRES	✔ Match tire type and size to unit ✔ Inflate to correct pressures ✔ Ballast to improve traction	• Reduced slippage and wear and improved efficiency from properly sized and functioning tires
TRACTORS	✔ Assess fuel efficiency performance ✔ Use timers for heater	• Reduced fossil fuel consumption • Reduced direct GHG emissions • Reduced electrical energy consumption
MACHINERY MAINTENANCE	✔ Regular tune-ups for fuel savings ✔ Match load with tractor ✔ Plan loads and trips with conservation in mind	• Extended life, improved efficiency and reduced waste • Reduced fossil fuel consumption
TILLAGE	✔ Reduce tillage ✔ Assess operations for one-pass opportunities	• Reduced fossil fuel consumption • Reduced direct GHG emissions • Reduced soil carbon loss

PRODUCTION

While agriculture is heavily energy-dependent, it's foreseeable that agriculture will become a generator of energy. For example, prime, marginal and fragile croplands could be growing woody energy crops. Small waterfalls and windy fields could be supplying on-farm electricity needs and feeding the grid with any surplus generated.

Follow maintenance schedules for machinery and equipment.



No-till greatly reduces the number of field passes, thus reducing both fuel use and labour.

FIELD CROPS FOR ETHANOL, BIODIESEL AND BIOMASS

For years, field corn and other grains have been grown as an energy crop. Ethanol is blended with gasoline as E10 (10% ethanol) and E85 (85%). The estimated net emission reduction for each is 4% and 37% respectively. By 2010, these reductions are expected to increase to 5% and 45% respectively.

Greater reductions are predicted when stover can be converted to ethanol. Soybean oil can be converted to biodiesel (about 1.5 gallons per bushel of beans). It has similar power and combustion qualities to diesel – without the emissions and particulate matter.

Perennial crops like switchgrass can also be converted to ethanol. The advantages of a crop like switchgrass are that it:

- is a perennial
- can be grown on fragile, marginal and degraded lands
- provides excellent wildlife habitat.

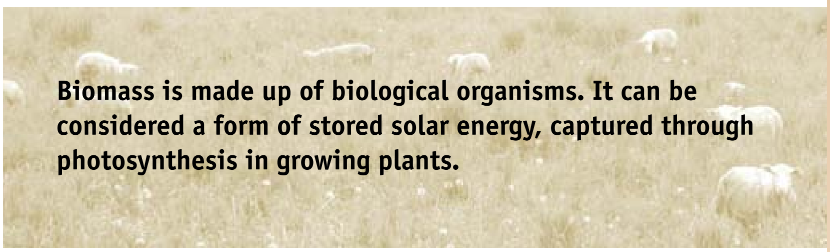
Field crop feedstocks can be used to produce ethanol fuels. Ethanol fuels help to reduce greenhouse gas emissions.

SHORT-ROTATION WOODY PRODUCTS FOR ENERGY

Woody plants can be grown on cropland for energy. Trees such as hybrid poplars, silver maple, willows, ash and cottonwood can be planted in plantation spacing (2 metres between trees and 3 metres between rows), grown for five to 20 years, then harvested. The sprouts or coppice growth can be re-harvested in five to 10 years on a sustainable basis from that point onwards.

Another variation for wood-crop energy combines fast-growing hardwoods with more valuable hardwoods in perimeter plantings such as buffer strips, wildlife corridors, field windbreaks and farmstead shelterbelts. The fast-growing hardwoods can serve as a nurse crop and provide an early harvest of biomass.

Woody plants can be grown on marginal and fragile farmlands for ethanol production or for biomass energy systems.



Biomass is made up of biological organisms. It can be considered a form of stored solar energy, captured through photosynthesis in growing plants.

SMALL HYDRO, WIND AND SOLAR POWER

The presence of a large wind energy installation at Pincher Creek, Alberta does not impede livestock grazing.

Fast-flowing water, wind and sun can also be harnessed to generate energy for domestic use and grid-supply. As the cost of hydro increases, as we better understand all the costs (including environmental) associated with it, and as we learn more about alternatives, the alternatives are becoming more attractive. The once-prohibitive capital investment of small generators, windmills and solar energy cells may be quickly outweighed by the revenue generated from feeding the grid.

WIND ENERGY

Wind energy is a fast-growing, green energy option for livestock producers.

Wind energy systems can be small or large. Small systems are designed to meet some or all of the operation's energy needs. Large systems – like the ones at Pincher Creek, Alberta and Shelburne, Ontario – are intended to supply the grid.

Small systems

There are three types:

- micro < 100W – suitable for electric fences, safety lighting
- mini 100W–10kW – generator backup; pumping for irrigation
- small 10–50kW – suitable for farm operation needs.

Wind turbines are of horizontal or vertical design and are set on towers 30 metres high.

The wind turns rotor blades on the turbine, which turns a gearbox or generator to produce an electrical current. Average wind speeds need to be greater than 13–15 km/hr. Stronger winds will generate more electrical power, reaching maximum power at 55 km/hr. Turbines shut down when wind speeds exceed 90 km/hr.

With a 10kW turbine and conversion of major appliances to gas, a small farm is off the grid. All electrical needs are met from turbine and battery storage. Installed cost: $60,000.

Large systems

Large wind systems are usually operated by power generators or by private companies contracted to supply energy to provincial girds. These systems come in sizes ranging from 300kW to 1.5mW. Each platform, tower and turbine covers up to 10 acres of land.

These wind turbines at Shelburne, Ontario present no restrictions to activities on cropland, forages and pasture.

These systems are located in areas of strong, consistent winds that are located near transmission lines. The best locations so far are coastal areas, the prairies and the tundra.

There are opportunities for land lease and royalty income. However, livestock producers should be well-organized and seek professional advice when approached by promoters of large wind-energy projects.

SOLAR ENERGY

Solar energy is being used on farms to heat homes, barns and water, run pumps and electrify remote fencing systems.

Passive solar techniques use dark-colour, heat-absorbing materials, and location of windows and roof overhang to attract heat for gradual release in colder conditions.

Active solar is deployed with solar water-heating systems that offset water-heating costs by using roof panels, antifreeze, pumps and a heat exchanger plumbed into the water heating system.

Photovoltaics, such as photovoltaic cells, are small, semiconductor devices that convert up to 15% of the sun's energy to DC currents. This form of solar energy is suitable for lighting, electronic equipment and electric fences. It's ideally suited to remote areas where grid connections are not economical.

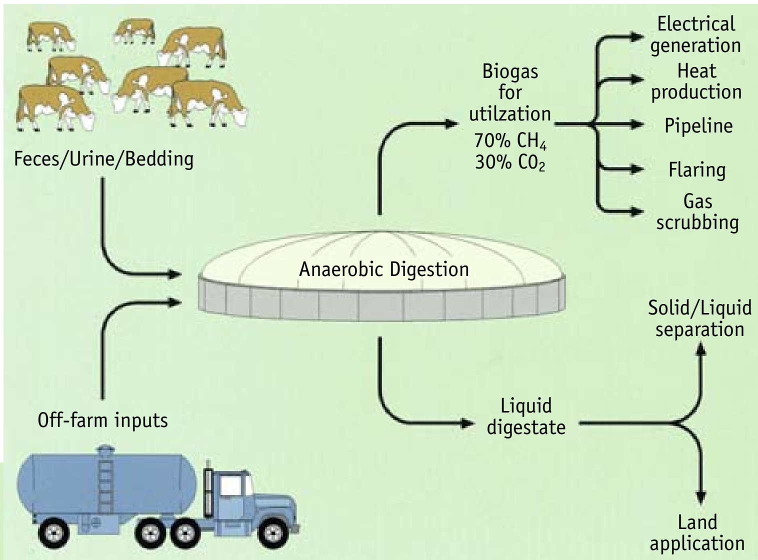
John Hill of Wentworth County relies on a hybrid system using solar and wind energy to service the electrical needs of his horticultural operation.

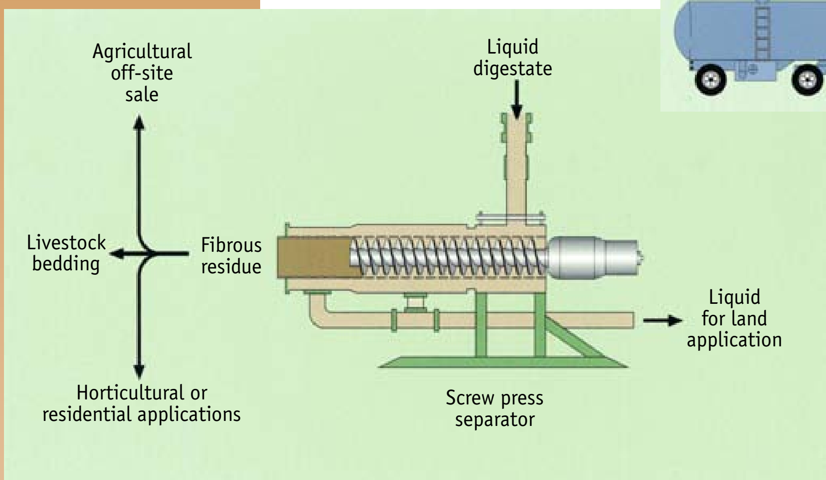
Liquid manure high in organic material is transformed by anaerobic bacteria into several end products, including "biogas" (carbon dioxide and methane). Biogas can be burned for heat or used to generate electricity.

ENERGY FROM MANURE – ANAEROBIC DIGESTION

Deriving energy from manure is obviously a win–win for livestock producers. The methane from biogas is 65% methane and 35% CO_2.

An anaerobic sequencing batch reactor or ASBR is a methane bio-digester that takes manure and creates electricity, organic fertilizer and water. The goal of this system is to transform methane into carbon dioxide and create usable energy (17–25 MJ/m^3).





Anaerobic digestion (AD) can perform most of the following functions:

- reduce manure volume for land application
- reduce or increase nutrient content of manure for land application
- recycle a product for reuse (e.g., water for flushing systems)
- reduce environmental impact (e.g., surface and ground water contamination)

▶ reduce odours and other nuisances
▶ reduce pathogens
▶ produce useful by-products for on-farm use or off-farm sales
▶ produce clean discharge
▶ reduce emissions of greenhouse gases
▶ produce renewable energy.

The biogas produced by anaerobic digestion units can be burned for heat or used to generate electricity.

How it works

Digesters function over a range of temperatures. Most work best at temperatures between 35 and 40°C (95–104°F).

Components include storage tanks, manure-handling equipment, digester tank, gas-handling equipment and electrical generation equipment.

Remaining outputs often require further processing prior to disposal or application.

Types of AD systems

Generally speaking, there are two AD system configurations suitable for Canada.

Completely mixed systems, as the name implies, consist of a large tank in which new and old materials are mixed. These systems are suitable for manure with lower dry matter content of 4–12%.

Plug-flow systems typically consist of long channels in which the manure moves along as a plug. These systems are suitable for thicker liquid manure (11–13% dry matter).

ADVANTAGES	DISADVANTAGES
• odour reduction • pathogen reduction • energy production	• increased capital cost, labour and maintenance • most suitable for very large operations • utility connections may be difficult

MANURE STORAGE AND HANDLING

Manure is a source of greenhouse gas. Solid manure is aerobic and emits carbon dioxide as it decomposes. The wetter portions of stored solid manure emit nitrous oxides. Liquid manure is anaerobic by nature and emits methane.

Livestock producers who have completed a nutrient management plan know that manure storage is a key consideration. Properly designed and sized storage systems result in less net nutrient loss, better containment of contaminated liquids, and reduced odours. These systems also reduce gaseous losses, particularly of ammonia, which affects the nitrogen content of the manure and its value as a fertilizer.

Livestock manure is handled and stored as a solid, semi-solid or liquid. Manure form depends on the type of livestock manure and what's added – the amount of dilution water plus the type and volume of bedding used. In Ontario, most livestock operations have either solid or liquid systems.

Solid manure emits nitrous oxides, and straw (bedding) is the main culprit. Long straw is worse than short or chopped straw (10 times more). Wheat and barley straw systems combined emit more than barley (1.5 times more). Covering manure with straw also increases greenhouse gas emissions. Summer emissions exceed winter emissions due to increased bio-activity.

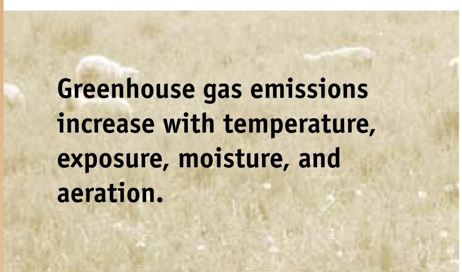
Liquid manure emits methane and ammonia. Most of the greenhouse gas from manure is methane from liquid manure.

Methane emissions depend on:

- manure volume – livestock numbers, feed and digestibility
- methane-producing potential – varies by manure and livestock type, feed quality
- manure storage and handling – liquid vs. solid, length of storage (e.g., over summer).

Most emissions from manure are from the storage of liquid manure (up to 80% of total emissions from manure):

- CO_2 loss was measured to be 20–30% of total carbon for cattle



Greenhouse gas emissions increase with temperature, exposure, moisture, and aeration.

Most manure-based emissions are from the microbial processes of anaerobic decomposition and partial denitrification.

- composted beef and dairy manure emits the least greenhouse gases relative to solid stacked and liquid
  - liquid emits 2–3 times more than piled solid
  - beef manure stored in piles emits 20 times more than compost (6 times more than composted dairy manure)
- manure is the prime source of greenhouse gas (methane and nitrous oxide) from the pork industry.

Most greenhouse gas emissions from agriculture come from stored manure during the first few months, due to anaerobic decomposition and denitrification.

Liquid manure storages are a source of methane from anaerobic decomposition, and of nitrous oxide due to denitrification from the crust of liquid manure storages. They can also be a large source of NH_3: 60–80% is lost from pig manure earthen storage, as a function of exposure, water content and pH.

Generally, larger operations have liquid systems to manage all liquids in the operation. Washwaters and, for dairy operations, milking centre wash liquids, are used to dilute the manure produced. This makes manure easier to handle. However, unless the manure is applied more than once a year, it is a source of greenhouse gases.

Managing all liquids is also important with solid systems. Clean water should be diverted, and contaminated waters (such as yard runoff) should be stored and managed separately – that's why some solid systems have separate liquid storages. This runoff can then be land-applied to supply additional nutrients to growing crops.

MANURE SYSTEMS AND GREENHOUSE GAS IMPACTS

MATERIAL	N_2O	CH_4	CO_2	NH_3
SOLID MANURE	High	Low	High	Medium
COMPOSTED SOLID MANURE	Medium to high	Low to very low	Very high	High to very high
LIQUID MANURE	Low	High	Low to medium	High to very high
COVERED LIQUID MANURE	Low	Medium	Low	High

BMPs FOR SOLID MANURE SYSTEMS

✔ **Keep bedding and manure dry and clean.**
For poultry, maintaining bedding moisture at 20–25% will reduce odour and NH_3 losses associated with damper litter or manure conditions. Some of the means to prevent excess water contamination include adjusting the height of drinkers to avoid spillage, and proper sanitation and ventilation.

✔ **Keep stored manure covered.**
Solid poultry pack manure with 25% moisture will emit less methane and nitrous oxide than manure storage and handling systems with more moisture. A shallow, solid pack manure system emits less than a deep, solid pack system.

✔ **Ensure proper ventilation.**
Use rapid-drying technologies to reduce microbial decomposition. Use belts, or slotted or ventilated floors.

✔ **Divert runoff and washwaters away from stored manure.**
Keep manure dry and minimize anaerobic areas that will emit nitrous oxide.

✔ **Remove manure from yards, feedlots and bedding areas frequently.**
This helps to keep manure dry.

✔ **Spread and incorporate more than once a year.**
This will reduce anaerobic conditions and subsequent methane release.

Covered manure storages are preferred.

Dry bedding emits less ammonia.

Wet bedding and solid manure are sources of ammonia, methane and nitrous oxide. Keep solid manure as dry as possible.

COMPOSTING

Is composting net-positive or net-negative for greenhouse gas? Carbon and nitrogen are placed in more stable forms, but how much ammonia and carbon dioxide are lost during the process of decomposition (composting)?

In theory, more aeration will lead to aerobic decomposition and CO_2 production (rather than methane). Poorly managed composting processes result in increased methane and ammonia generation. Composted manure produced 7% and 80% less CO_2 equivalents than raw manure in winter and summer respectively. Generally, 25% less greenhouse gas is produced from composted manure vs. raw manure systems. Other studies found that passive aeration of composted manure generated approximately two times more net greenhouse gas than actively composted manure.

There are fewer nutrients in runoff from compost than from raw manure. During the composting process, ammonia and methane are emitted at the initial phases and nitrous oxide during the mid-phases.

To compost poultry manure to a stable endpoint: maintain moisture at 40–60% (greater than 60% can result in leaching), temperatures at 135–145°F, sufficient oxygen from turning for aerobic decomposition, and pH of 5.5–7.5 (greater than 8 results in ammonia volatilization).

Properly composted manure will emit less greenhouse gas than raw manure.

BMPs FOR LIQUID MANURE SYSTEMS

✔ **Reduce manure liquid content.**
Divert clean water, washwaters and wastewaters away from storage. This will reduce anaerobic conditions conducive to ammonia and methane emissions.

✔ **Cover storage where possible.**
Covering manure storage will reduce emissions.

✔ **Agitate and aerate to reduce anaerobic conditions in order to lower methane emissions.**
This will convert ~30% of the carbon materials to CO_2, but will not prevent anaerobic decomposition. Use passive agitation or alternative energy source to drive agitator/aerator.

✔ **Reduce storage time with more frequent applications. Use side-dress applications to reduce methane and ammonia emissions.**

✔ **Treat manure.**
Use solid–liquid separation or anaerobic digestion to reduce emissions and convert them to renewable energy.

Liquid manure storages are sources of methane and ammonia.

CONSIDERATIONS FOR COVERS

Covering storages can reduce temperature and methane. Ninety percent of manure's methane potential is lost to the atmosphere from earthen manure storages. Covered storages can also reduce additional moisture, accelerate anaerobic conditions, and lessen the amount of methane lost.

However, straw covering of stored liquid dairy and pig manure can increase emissions depending on the greenhouse gas, straw type and length, and season. Straw and other high-carbon bedding are a source of food and energy for microbes. Some of these microbes will convert carbon compounds to methane and others will reduce nitrogen compounds to nitrous oxide.

Winter covering with straw can reduce N_2O, CH_4 and CO_2 emissions by 12%, 87% and 53% respectively, whereas summer covering of stored liquid manure will have the opposite effect with increases of 42%, 55% and 33% respectively. Covered storages and reduced temperatures can reduce NH_3 losses by up to two-thirds.

Studies of other covers revealed:

- a thin layer of mineral oil was found to reduce NH_3 loss by two-thirds
- ammonia can be trapped by acidic peat in the form of ammonium ($NH_3 + H^+ = NH_4^+$).

Divert clean water away from manure storages to reduce emissions.

Energy-passive agitation and aeration systems will introduce oxygen and reduce emissions.

Manure treatment such as solid-liquid separation can reduce emissions.

LIVESTOCK YARDS

Livestock yards can be paved or soil-based. As we've seen, anaerobic conditions will generate greenhouse gas. Maintenance can reduce anaerobic conditions and reduce soil mixing of manure and bedding, which in turn will reduce methane and N_2O production. By removing manure wastes frequently, you can reduce methane and N-oxide by 10%.

MANURE SYSTEMS AND TREATMENTS AND GREENHOUSE GAS IMPACTS		
GREENHOUSE GAS	WINTER AND SPRING *	SUMMER *
AMMONIA	0.27 $g/m^2/day$	0.45 $g/m^2/day$
NITROUS OXIDE	3.3 $ug/m^2/day$	6.5 $ug/m^2/day$
METHANE	185 g/m^2	57.3 g/m^2

*if feeding areas included

BMPs FOR FEEDLOT AND YARD RUNOFF MANAGEMENT

Livestock yards and feedlots are used by dairy and beef producers to provide confined outdoor space for feeding, exercising or loafing. Whether paved or dirt, they are located to take advantage of natural slopes so that rain and roof runoff helps keep these areas clean.

Yard runoff contains nutrients and organic material. Unless managed effectively, yard runoff can put groundwater and surface water at risk of contamination.

✔ **Determine the risk of contamination.**
Consider livestock numbers, the size and other physical characteristics of the lot, as well as rainfall intensity, duration, and frequency.

✔ **Divert uncontaminated water.**
Water from rain, snow, snowmelt, roofs and eaves should not have contact with manure on exercise yards.

✔ **Clean paved areas regularly.**

✔ **Fence cattle out of any manure and runoff storages.**

Maintenance can reduce methane and nitrous oxide production.

BMPs FOR MANAGING RUNOFF FROM FEEDLOTS AND YARDS

BMP OPTION	DESCRIPTION	TIPS
DIVERT CLEAN WATER  **A well-designed eaves system can divert clean water away from manure storages.**	• Roof the yard or scrape manure to roofed area. All roofs that would contribute to runoff from the feedlot should have gutters, downspouts, and outlets that discharge water away from the feedlot. • Where roofing is not practical or feasible, clean water diversion and frequent maintenance will still complement other management systems.	• To complement this expensive option, follow a strict manure maintenance program. • To reduce the volume of contaminated water produced and the amount of solids eroded from the lot, try these measures: ○ adequate eaves, rainwater diversion, clean water drainage system (independent of any wastewater system) and in some cases, berms to divert severe storm and meltwater runoff from upslope of the facility.
DIVERT UNTREATED WATER AND MANURE TO LIQUID STORAGE  **Yard runoff can be diverted to liquid manure storages.**	• Yards need to be designed to convey contaminated water and all precipitation (including storm events) to the liquid storage. • Provide diversion to separate storage (suitable for dirt livestock yards and feedlots).	• Concrete curbs, gutters and an outlet must be part of the paved yard design. • These systems work best with the following management practices: scraping of manure, bedding and wasted feed, plus unplugging the outlet area. • Yards need to be shaped to channel contaminated water and all precipitation (including storm events) to the designated storage (pond/earthen storage). • Properly designed curbs, concrete gutters or grassed diversions and a picket-fence outlet must be part of the paved yard design. • These systems will ONLY work effectively with the following management practices: scraping of manure, bedding and wasted feed, as well as unplugging the outlet area.
DIVERT AND TREAT RUNOFF  **Vegetative filter strips can reduce anaerobic conditions by treating yard runoff.**	• Lot runoff is diverted to a vegetated filter strips system designed to intercept and treat runoff by settling, filtration, dilution and absorption of pollutants, and infiltration into the soil. • Runoff can be collected and transferred by diversions, curbs, gutters, lot paving, and, in some cases, by pumping. • A settling basin is needed to remove solids. Liquids go to a vegetative infiltration area where the liquid is filtered and infiltrates the soil.	• Liquid materials from separate storages can be managed like liquid manure IF solids are prevented from entering pond or they can be part of a treatment system.

NUTRIENT MANAGEMENT PLANNING AND APPLICATION

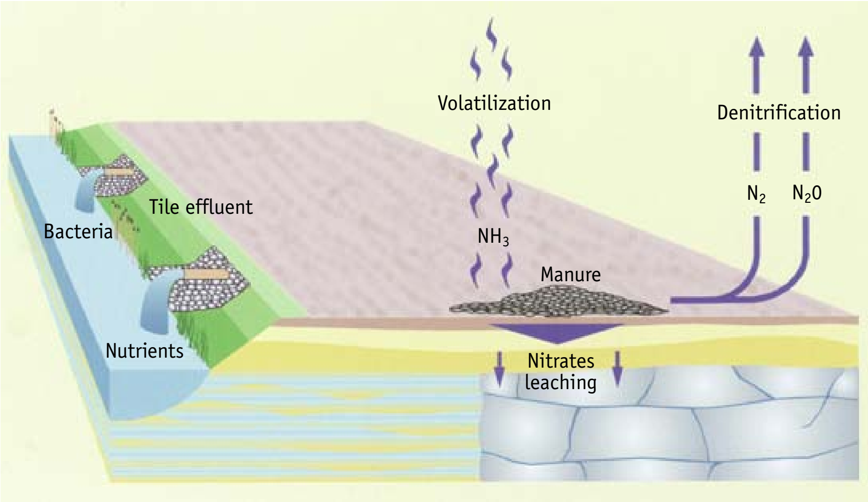
Manure is both a source of nutrients and a potential pollutant.

Manure contains valuable nutrients and organic matter that are beneficial to young, growing crops. Most (78%) of the nitrogen consumed by livestock ends up in urine and feces. Some of the nitrogen is lost as NH_3 (up to 80%) from manure. The nitrogen content of manure varies, but typically is around 2% of dry weight.

But these same nutrients can be harmful to your water supply when poorly managed.

It takes careful planning to reduce greenhouse gas emissions from applied manure and other wastes. We'll explore options in the upcoming sections.

If it's not incorporated, applied manure will release ammonia. If applied on wet soils and when the crop can't use the available nitrogen (e.g., fall-applied), it can also contribute to the production of nitrous oxides.



Ammonia can be lost from croplands directly through volatilization or indirectly through denitrification (if it's converted to ammonium and then to nitrates). Around 2% of manure is nitrogen. It comes in two forms: organic and inorganic. The inorganic fraction is ammonium/ammonia. The organic fraction will mineralize to form ammonium/ammonia. Both sources can lead to emissions of ammonia. Ammonia can react with water to form ammonium in soils and water. If the ammonium is not taken by crops and other vegetation, it can be nitrified (which is also a source of N_2O). Nitrified N can leach or denitrify to form N_2O.

Side-dress manure to reduce emissions.

If well-managed, manure additions will add SOC and nutrients, while reducing carbon and nitrogen losses from the system.

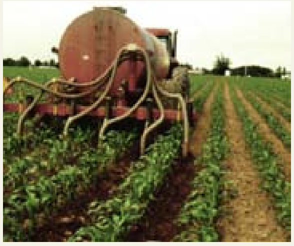
PLANNING

A nutrient management plan (NMP) is a working document and management tool that you can use to match farm-based and purchased crop nutrients with the nutrient needs of your crops. It also serves as a statement for societal assurance, demonstrating that nutrients are being applied at rates and with techniques that will minimize the risk of water pollution and greenhouse gas emissions.

10 STEPS TO MAKING IT WORK

Nutrient management planning is an in-depth process. But it doesn't have to be overwhelming – especially when you take it step-by-step.

Remember that your plan is not and should not be set in stone. Planning is a dynamic process, just as your operation is. That's why some steps are revisited, whether from season to season or year to year, as you evaluate your progress.

STEPS	DESCRIPTION	KEY COMPONENTS	
1. SET GOALS	• State your direction for nutrient management planning – helps with decision-making.	• Establish why you're doing the plan. • Seek advice. • Create a vision for what the plan will accomplish.	
2. TAKE INVENTORY	• Create a picture in time of what's currently available within your operation – if you don't know what you've got, you don't know what you need.	• Identify resources on the farm. • Describe site characteristics. • Detail current management practices.	
3. INPUT AND ANALYZE DATA	• Apply what you have against what you need to do.	• Use NMAN and MSTOR. • Determine land base requirements. • Conduct risk assessment.	
4. INTERPRET RESULTS	• Based on your data analysis, develop options – to manage risk, decrease input costs, and handle all nutrients generated.	• List possible management practices. • Identify changes to structures and facilities. • Remember the systems approach.	
5. MAKE DECISIONS	• Select options to meet your goals.	• Remember economics and common sense. • Honour personal and business goals. • Use available resources. • Set proper application rates. • Honour separation distances.	

STEPS	DESCRIPTION	KEY COMPONENTS
6. ACT	• "Walk the talk" to meet your goals.	• Make an operational plan. • Complete day-to-day activities. • Account for the impact of outside forces (e.g., weather, markets).
7. KEEP RECORDS	• Document what actually takes place – develop your own information for future planning, while showing accountability for your actions.	• Maintain: ○ application records ○ livestock records ○ cropping records ○ monitoring records.
8. MONITOR	• Observe the impact of what you do to determine: ○ is production on track? ○ are ground and surface water protected? ○ are nutrients cycling properly?	• Monitor: ○ nutrient levels in soil and manure as it relates to crop performance ○ water quality in wells and tiles ○ livestock performance ○ nuisance impacts.
9. ADJUST	• Fine-tune your plan, and upgrade technology where appropriate.	• Use information from record-keeping and monitoring. • Modify plan by repeating Steps 3 to 6.
10. PLAN FOR THE UNEXPECTED	• Develop a contingency plan.	• Identify resources. • Communicate to others involved. • Document actions.

SOIL TESTING

Soil testing will give you an index of likeihood of crop response to applied nutrients. Applying what your crops need, when they need it, will:

- ▶ improve crop growth
- ▶ improve crop tolerance to insects and diseases
- ▶ improve crop maturity and quality
- ▶ increase yields
- ▶ lower input costs
- ▶ protect the environment – less leaching, runoff and greenhouse gas production.

Make N-applications more precise with a soil nitrate test.

Tests are relatively inexpensive and more than pay for themselves.

✔ **Test your soils at least every three years** to manage soil pH, phosphorus, potassium and magnesium – and micro-nutrients in some cropland

- ▶ take them at the same point in the rotation and time of year for consistency.

N-TESTING

The amount of nitrate–nitrogen present in your soil at planting time can indicate a soil's capacity to supply nitrogen. In general, the higher the concentration of nitrate–nitrogen in the soil, the lower the amount of nitrogen required for optimum yields.

✔ **Modify N application rates according to nitrate test results.**

HOW TO CALIBRATE YOUR SPREADER

Based on their spreader's capacity, many farmers estimate how much manure is spread by counting the number of loads being applied to a field. Although this may seem to work well, it doesn't take into account the different densities of the manure or whether the spreader is being filled to meet the manufacturer's specifications.

You can use several methods to measure your spreading rates. One quick method for solid manure involves weighing the manure applied onto a plastic sheet placed in the path of the spreader. A method for liquid manure uses a straight-walled pail to measure depth of application.

Nutrient Use Efficient (NUE) best management practices will reduce emissions and provide nutrients when and where needed.

BMPs FOR NUTRIENT USE EFFICIENCY (NUE)

Nutrient Use Efficiency (NUE) refers to how well a crop uses available soil nutrients such as nitrogen. The more taken up and used by the crop, the less nitrogen remains in the soil to be leached, volatilized or denitrified to form nitrous oxide.

Nutrient management systems that strive to improve NUE do the following:

- make the required amount of available forms of nitrogen available when the crop needs them
- place nitrogen where the crop roots can access them
- reduce the amount of nitrate in the soil when the crop can't use it
- account for and manage all sources of plant-available N
- manage other cultural practices and conditions for NUE (e.g., soil and water management).

BENEFITS

- reduced nitrous oxide production
- increased carbon dioxide uptake by crops (growth and yield)
- increased yields and improved product quality
- lower fertilizer input and application costs – less energy and greenhouse gas produced for N-fertilizers
- less runoff and groundwater contamination

Improve NUE with legumes in your rotation.

BMPs FOR IMPROVING NUE IN FIELD CROPS

✔ **Rotate crops to maximize NUE.** Growing a legume or forage before a high N-demanding crop will improve NUE. Legumes and forages lose less plant N from the system.

✔ **Select varieties for more NUE.** Varieties that use water efficiently will improve overall NUE.

✔ **Reduce tillage.** Less tillage means that root zone placement is better – preferable to surface broadcast.

✔ **Use appropriate N source.** Use ammonium for low-yield expectations and ammonium + nitrate for high-yield expectations.

Use cover crops to trap nitrates for the next crop.

✔ **Time nutrient application appropriately.** Use split application for grains and oilseeds, but no pre-plant N if N-levels are high.

✔ **Use cover (or trap) crops in the off-season** to capture and hold plant-available N for future crop use.

BMPs FOR APPLICATION

To complete your system, consider the following best management practices for application that also reduce greenhouse gas emissions. Beyond nutrient management planning and NUE, your key considerations will be:

- ▶ timing – respecting season and weather conditions
- ▶ rate of application in relation to crop needs – minimizing spillage and ensuring the product is hitting the target
- ▶ method of application – minimizing loss and improving NUE.

Winter application leads to increased losses of methane, ammonia and nitrous oxides.

TIMING

✔ **Avoid late fall and winter application.** Application at these times leads to high denitrification rates. During snowmelt, the soil becomes saturated or anaerobic, leading to methane and nitrous oxide emissions.

✔ **Avoid application prior to anticipated storm events and snowmelt** whenever possible to reduce nutrient loss, runoff, soil compaction and tile effluent. Avoid spreading if rainfall occurs shortly before application, or heavy rains are forecast within 12–24 hours of spreading on tile-drained lands. Note:

- ▶ runoff will wash manure to areas of standing water where denitrification and anaerobic decomposition will continue until local carbon and nitrogen sources are depleted
- ▶ it's best to incorporate before rain to reduce loss by volatilization – in cool damp weather, NH_3 loss is reduced
- ▶ avoid applying liquid manure when tiles are running.

Reduce emissions from soils with side-dress applications.

✔ **In summer, plan side-dress applications of manure to growing row crops on cereal stubble or between cuts of forages.** This avoids crop damage, and keeps applications off of crop foliage.

✔ **Incorporate manure within 24 hours of application.**

Incorporate within 24 hours or inject into root zone to reduce nutrient loss.

Where possible, lower application rates of liquid manure so as to keep soil drier and release fewer emissions.

Injection methods reduce ammonia loss.

Avoid surface application on steeply sloping lands adjacent to environmentally sensitive areas.

RATES

✔ **Reduce rate to minimize denitrification.**

✔ **Consider lower rates of liquid nutrient application** (<15,000 gallons/acre). This translates into lower soil moisture conditions, so that less methane and nitrous oxide is lost.

✔ **Ensure application rates of all sources of N approximate economic yield.** For organic N, add only about one-half of what the crop needs.

APPLICATION METHOD

✔ **Try for immediate incorporation** wherever possible.

APPLICATION METHOD	NITROUS OXIDE LOST kg N_2O-N/ha
Incorporation	2.7
Injection	4.8
Broadcast	5.6

✔ **Maximize soil–manure contact to reduce ammonia volatilization.** These three application methods produced less ammonia than broadcast: banding liquid manure (39% less), trailing shoe (43%), and shallow injection (57%). However, banding/injection of liquid manure may lead to more denitrification due to concentrated C+N in warm moist conditions. But injection followed by soil covering can reduce NH_3 volatilization. Injection will reduce ammonia loss.

✔ **Avoid manure fertigation.** Irrigation of manure emits excessive N_2O because of saturated conditions. If irrigating, don't spray too high above ground.

✔ **Avoid application during hot, humid or windy weather.** Odours are more intense and ammonia loss increases at these times.

✔ **Have regard for neighbours' concerns** when spreading near their homes.

✔ **Where suitable, pre-till tile-drained lands before applying liquid manure.** This will break up large pores and reduce infiltration to tiles. Care and consideration must be given to soil conservation. Maintain as much residue cover as possible. Note: pre-tillage may not be necessary if a visual system for outlet monitoring exists.

✔ **Inspect drains** to ensure the absence of manure.

✔ **Avoid surface application on steeply sloping lands** adjacent to watercourses, lakes, ponds and wetlands.

✔ **Monitor and be prepared to react to any spills.**

PASTURE AND GRAZING MANAGEMENT

Besides being more productive, well-managed pastures can reduce emissions. In fact, they can be a net "sink" (holding and converting more greenhouse gases than they release). Well-managed pastures use nutrients more efficiently, and don't foster the anaerobic conditions that promote greenhouse gas emissions.

The higher quality forages from management-intensive grazing systems generate less methane from ruminants and result in a more efficient feed-to-product ratio. High quality forages lead to 50% lower methane emissions from grazing cattle. Legumes in pasture improvements lead to 10% lower methane emissions.

Poorly managed pastures can be a net source of greenhouse gas. Methane is produced from grazing ruminants and poorly drained pasturelands. Ammonia and nitrous oxide are emitted from deposited manures and soils. Over-grazing can destroy new growth and deplete root reserves.

Management-intensive grazing systems are more nutrient use efficient and generate less greenhouse gas than conventionally managed pastures.

PASTURE MANAGEMENT

A controlled grazing system improves forage quality.

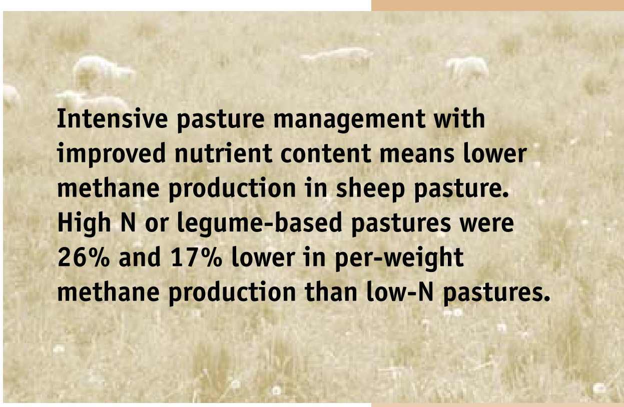
Continuous grazing results in wasted forage, decreased productivity and lower liveweight gains per acre of land.

Pasture management is a planned system of pasture production that includes establishment, improvement, grazing oversight, fencing, environmental protection, water supply, animal health and cost considerations.

Over-seeding is a pasture improvement practice that also helps to reduce emissions.

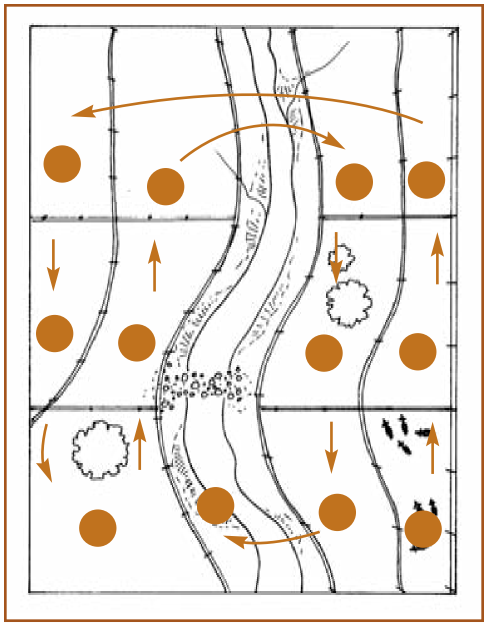
The goals of your pasture management system include:

- proper soil fertility
- careful pasture crop selection
- effective weed control
- sustainable grazing
- a well-planned fencing system (for intensive grazing management)
- planned water–shade–mineral supply
- attention to animal health, and
- protection of riparian areas.



Intensive pasture management with improved nutrient content means lower methane production in sheep pasture. High N or legume-based pastures were 26% and 17% lower in per-weight methane production than low-N pastures.

More efficient livestock gain and finer forage intake make for lower methane emissions from ruminants, less soil disturbance and less anaerobic conditions.



An effective managed intensive grazing (MIG) system requires careful attention to pasture quality, timing and grazing animal behaviour.

The aim of grazing management is to allow enough top growth and root reserves for regrowth following grazing, plus the ideal length of recovery time to meet that goal.

For many reasons, any grazing areas that approach riparian areas (i.e., around watercourses, wetlands, ponds and lakeshores) need protection. Riparian areas are important carbon sequestration zones and can use leached nitrates from cropland or pastures before they reach surface water. Total exclusion through grazing management and fencing when required will also help reduce greenhouse gas emissions.

Managed pastures, with the judicious use of fenced paddocks, are one of the most sustainable forms of agricultural crop production. Well-managed pastures, including cropland converted to managed pasture, can be more productive, profitable and environmentally responsible. Erosion rates are drastically reduced, and energy consumption is considerably less. Denitrification rates are substantially lower and soil carbon sequestration rates are higher. Surface and ground water quality is improved. Wildlife habitat and corridor opportunities are greater.

Well-managed pastures sequester more greenhouse gases than they emit.

BMPs FOR PASTURES

ESTABLISHMENT

✔ **Soil test!** Fertile pasture soils will help pasture crops become established, grow and compete with weeds.

- ▶ Test one year before establishment.
- ▶ Keep P+K levels medium – forage/pasture species are big feeders
  - ▷ P+K levels are most often the most limiting factors
  - ▷ higher P+K levels translate to improved NUE.
- ▶ Sample unique areas (e.g., eroded knolls for retirement) separately.

Use pasture mixes suitable for local site conditions.

SEEDING MIXTURE

✔ **Select a mixture** that meets its purposes for site conditions, growth, gain targets, and use. Species that are readily digestible, durable, fast-growing, and nitrogen and water efficient are more environmentally friendly.

SEEDING TECHNIQUES

✔ **Use companion crops** such as spring cereals only in areas prone to erosion.

✔ **Plant seeds less than 1 cm deep.**

✔ **Use no-till where possible.** No-till planting disturbs less soil. It can be used after a cover crop is killed and prior to establishment.

Use no-till planting equipment where possible – less soil is disturbed and this keeps carbon in the topsoil.

WEED CONTROL

✔ **Kill perennial weeds** prior to establishment.

✔ **Clip weeds** during early establishment and on an as-needed basis.

Weed control during establishment will prevent long-term weed pressure problems.

IMPROVEMENT

✔ **Rejuvenate, where appropriate, to improve undergrazed areas with low fertility.**

- ▶ Soil test and improve fertility to increase survival and production of desired species.
- ▶ Plan and follow a grazing management plan to sustain production.

✔ **Renovate to increase productivity by introducing pasture species without disturbing the soil.** Successful renovation depends on:

- ▶ proper pasture mix selection
- ▶ site preparation
- ▶ timing of seeding
- ▶ soil fertility and moisture levels during establishment, and,
- ▶ weed control during establishment.

BMPs FOR GRAZING SYSTEMS

The aim of grazing management is to allow enough top growth and root reserves for regrowth following grazing plus the ideal length of recovery time to meet that goal. The following measures help to maintain a sustainable, environmentally friendly pasture.

✔ **Spread manure evenly.** Keep pastures in excellent condition.
✔ **Encourage beneficial insects.**
✔ **Feed winter rations over a large area.**
✔ **Stockpile high quality pasture.**
✔ **Move bedding pile frequently.**
✔ **Feed on level ground or gentle slopes.**

BENEFITS OF CONTROLLED GRAZING

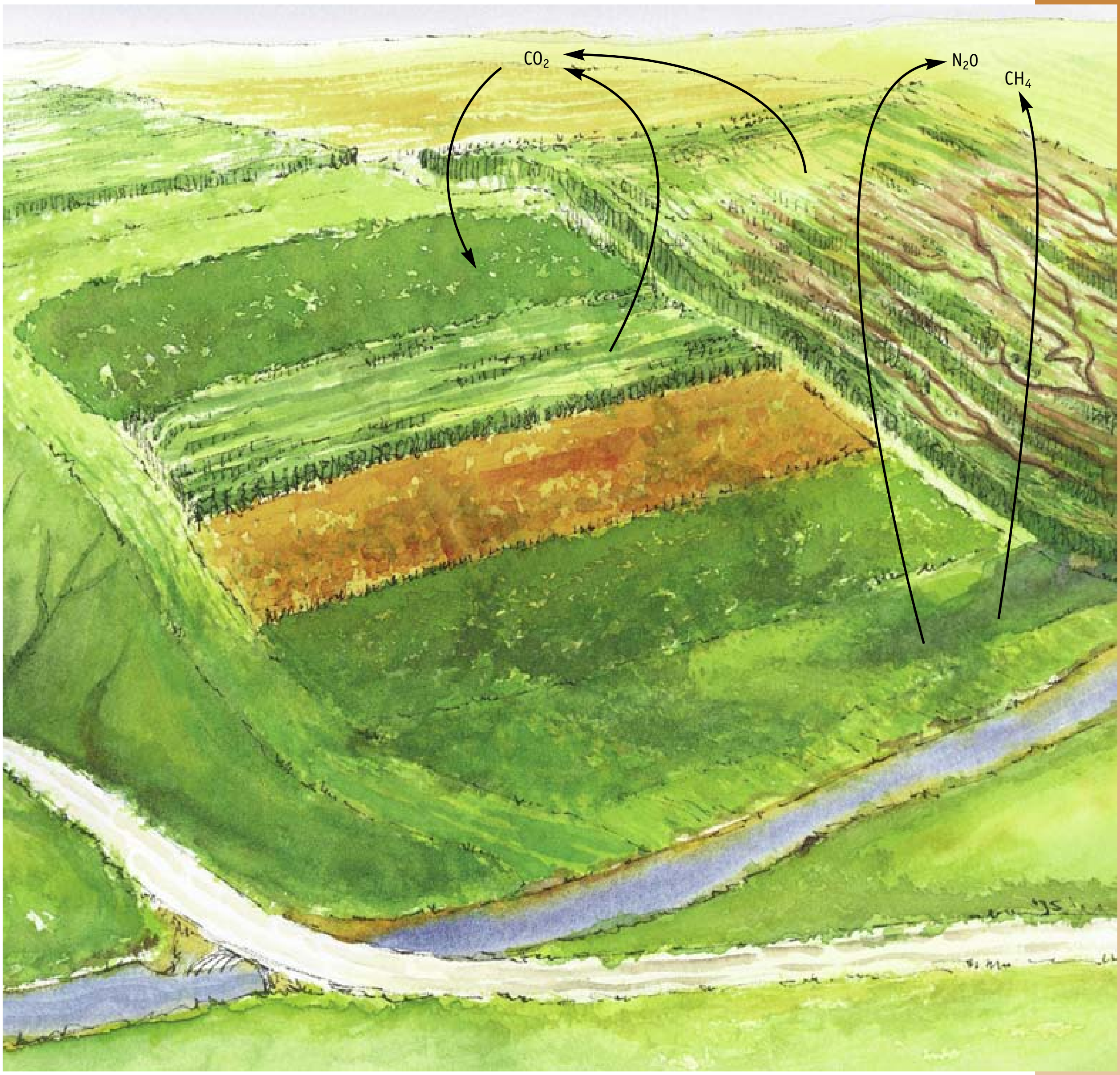
- ▶ more productive cows
- ▶ improved liveweight gains
- ▶ lower methane production/pound of meat – due to higher quality forages
- ▶ improved pasture = better SOC sink (CO_2)

MANAGEMENT PRACTICE	DESCRIPTION OF GRAZING SYSTEM	WHEN TO USE THIS PRACTICE	MANAGEMENT GUIDELINES	COMMENTS
SEASON-LONG	• stocking throughout the season • animals have maximum forage selectivity	• very-low stocking rates (hobby farms or very small operations) • minimal impact • observed livestock behaviour follows forage growth	• livestock should not spend too much time near floodplain or banks • requires management features such as salt feed, shade, water and barriers to encourage livestock away from sensitive areas	• forage species can be over-grazed – seasonal damage is not prevented • may work with corridor fencing where livestock are excluded with this system, particularly if near narrow-channel watercourses and drainage ditches • not suitable for pastures near wetlands and ponds • **not an optimal emission-reducing practice unless BMPs are employed to discourage congregation and pasture management practices help keep forage palatable**
TIME-CONTROLLED GRAZING (OR SHORT-DURATION)	• livestock are rotated through several paddocks over short intervals on a recurring basis • high stocking rates for short periods of time – with rest periods for recovery	• suitable for grassy pastures near riparian areas with fenced paddocks • useful for dairy and other high-production livestock operations	• in most riparian areas, livestock should be moved when 4-6 inches of forages remain • rate of rotation varies with the rate of plant growth • specialized timing and intensity of grazing can be used to control weed growth	• rest periods must be long enough for suitable recovery • grazing times must be short enough to prevent rapid re-grazing • possible damage in spring • **moderately effective for emission reduction as manure is well-distributed, wet areas are avoided and forage remains palatable**
SEASONAL ROTATION (OR DEFERRED ROTATION)	• grazing is delayed until key pasture plants have reached desired growth stage and when soil conditions are less prone to damage	• suited for low-density stocking near wide-channel streams and middle-reach rivers to avoid damage in spring and plant stress in mid-summer	• short grazing periods – not managed as intensively as time-controlled grazing • implement with alternative watering systems and other practices that encourage animals to congregate away from streambanks	• riparian areas should be in healthy condition prior to using this system • helps newly planted buffer areas get established • **emission-reduction friendly, this method helps perennial plants to become established**

MANAGEMENT PRACTICE	DESCRIPTION OF GRAZING SYSTEM	WHEN TO USE THIS PRACTICE	MANAGEMENT GUIDELINES	COMMENTS
THREE-PASTURE REST-ROTATION SYSTEM	• three-pasture rotation system • only two pastures grazed each year • rotation schedule for pastures: *year 1*: spring grazing; *year 2*: late summer and fall grazing; *year 3*: complete rest	• ideally suited for pasture systems near riparian areas – riparian areas can be favoured to allow for restoration or improved pastures to become established • inappropriate for use in shrub-dominated riparian areas since young woody plants do not have sufficient rest time to become established	• a semi-extensive grazing practice that rests each pasture area once every three years • needs to be managed to protect against streambank degradation in spring and forage depletion in fall • requires management features such as salt, feed, shade, water and barriers to encourage livestock away from sensitive areas	• if used in woody riparian areas, limit grazing time during the late summer rotation to when herbaceous crops are only half used – this will limit livestock feeding on woody plants • adding more pastures will increase the amount of time land is rested and will further protect woody species • allows for grazing restored areas during prolonged droughts • **emission-reduction friendly, as rest allows regeneration and carbon sequestration**
SITE-SPECIFIC MANAGEMENT	• paddocks are designed to maximize grazing efficiency and minimize risk – using pasture species, growing season and site position as factors	• in riparian areas where site differences are distinct (e.g., wet floodplain and degraded ravine slopes)	• drier sites are grazed early and for short durations; wetter sites are deferred and also grazed for short time interval	• acceptable low-density grazing in grassed ravines, floodplains and adjacent to wetland areas, where access can be controlled to the preferred (drier) season, and for very short periods to control weedy vegetation • **very emission-reduction friendly, as site conditions are grazed during ideal times to minimize impact**

CROP AND CROPLAND MANAGEMENT

CROPLAND: BOTH A SOURCE AND A SINK



Cropland can be a source or sink for greenhouse gases. Poorly managed soils are prone to degradation and loss – a prime source of CO_2. Wet and compacted soils can be a source of nitrous oxide and methane. Well-managed soils are a net sink for carbon and emit considerably less gas.

SOURCE

Waterlogged soils emit nitrous oxide and methane.

Cropland can be a source of **direct emissions** in the following ways:

- **soil organic carbon (SOC) loss** – conventional row-cropping and tillage practices will reduce soil organic matter and carbon levels
- **methane emissions** – methane from cropland is normal and increases in anaerobic, or partially anaerobic/compacted soil conditions
- **nitrous oxide loss** – greatest in warming, moist-to-wet soil seedbeds with high residual nitrogen levels (e.g., unincorporated, surface-applied manure).

Indirect emissions result from two processes:

- **soil erosion** – soil loss accelerates SOC loss and compensating fertility requirements
- **ammonia volatilization** – surface-applied manure and other nutrients lead to ammonia volatilization.

You can **minimize losses** through:

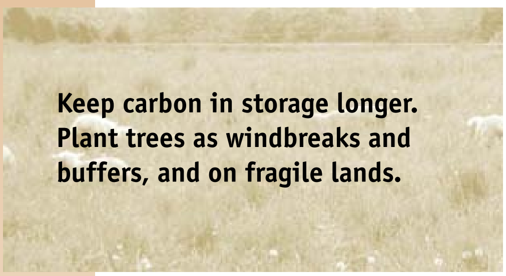
- **soil protection** – with reduced tillage, residue management, cover crops and measures that protect soil from wind and water erosion
- **soil water aeration** – using practices that manage soil moisture levels, reduce compaction, and increase aeration, e.g., through tile drainage, to reduce methane and N_2O emissions.

Protected and productive soils help reduce emissions from agriculture.

SINK

You can **reduce emissions** through the following measures:

- **SOC additions** – best management practices such as additions of manure and other organic materials, and the growth of forages, cover crops and other soil-building crops increase SOC levels
- **organic N pool** – the addition of nutrient-rich materials, legumes and trap crops increases organic N levels.



Keep carbon in storage longer. Plant trees as windbreaks and buffers, and on fragile lands.

BMPs FOR CROPPING AND TILLAGE

FOR LIVESTOCK OPERATIONS			
GREENHOUSE GAS BMP	**BENEFITS FOR EMISSION REDUCTION**	**DESCRIPTION**	**TIPS TO MAXIMIZE BENEFITS**
IMPROVED FORAGE PRODUCTION 	**Moderate C addition** • reduces methane from ruminants • reduces N fertilizer **Reduced N_2O loss** • improves soil quality	• the proper establishment, maintenance and harvest of grass and/or legume crops for pasture, hay or haylage • feed will improve soil quality and fertility, and reduce greenhouse gas emissions	• seek opportunities in current cropping program – trade with neighbour • select varieties for hardiness and palatability • maintain P + K levels for maximum productivity • try no-till and reduced tillage methods for establishment
	Forages reduce soil C loss, but that's not all they do. They also reduce N loss, add organic matter and improve aeration, further reducing CH_4 and N_2O losses.		
CROP ROTATION 	**Low C addition** • improves soil quality • improves production • decreases pest pressures	• crop rotation is the practice of alternating crop families – in some cases annually – on cropland • crop rotation diversifies the ecology of the cropping system, so it can reduce weed and other pest pressures, improve seedbed structure and increase overall productivity	• plan for longer rotations if possible (i.e., more crop types, more years), especially if forages included • rotate between different families of crops (i.e., grasses vs. broadleaves) • include cover crops in rotation to trap nitrogen
	Crop rotations with a high proportion of continuously cultivated crops have been shown to have 9% less soil organic matter than more conserving rotations that include grasses or legumes.		
COVER CROPS 	**Low C addition** • reduces N_2O loss • improves soil quality • improves production • decreases pest pressures	• a cover crop is one that is specifically intended to provide protection to the soil • often it refers to any crop that improves or regenerates the soil	• planning is key – ensure good fit in crop rotation • timing is everything – ensure cover crop control is feasible and N-release is properly timed
	Cover crops have half the C storage potential of no-till, and also contribute to minimizing N_2O emissions when left to live over winter and be killed off in the spring. Cover crops are particularly useful to those operations where no-till is not feasible – but soil cover is important.		

FOR LIVESTOCK OPERATIONS

GREENHOUSE GAS BMP	BENEFITS FOR EMISSION REDUCTION	DESCRIPTION	TIPS TO MAXIMIZE BENEFITS
NO-TILL	**Moderate C addition** **Reduced N_2O loss** • improves soil quality • reduces soil erosion	• in no-till systems there is minimal disturbance by planting equipment and residue left to manage from the previous crop • depending on the crop, most of the soil surface is covered throughout the year	• spread residue evenly behind the combine • match tillage equipment to your soil type • modify planting and crop input equipment • modify pest management to deal with pressure shifts
	**No-till slows down the process of decomposition, allowing substantial C gains, lower fuel usage and N_2O fluxes. No-till is estimated to emit less greenhouse gas than conventional tillage systems. From the standpoint of minimizing emissions, no-till is most suitable to those livestock operations with liquid manure.**		
REDUCED TILLAGE	**Reduced C loss** **Low C addition** **Reduced N_2O loss** • improves soil quality • reduces soil erosion	• reduced tillage systems involve reducing the number of passes with tillage equipment and managing the residue left from the previous crop • these systems leave residue cover on the soil surface	• spread residue evenly behind the combine to eliminate windrows • choose residue levels that meet soil protection requirements and crop development expectations • match tillage equipment to your soil type • modify planting and crop input equipment
TIMELY TILLAGE	**Reduced CH_4 losses** **Reduced N_2O loss** • reduces runoff • reduces erosion • improves productivity	• the goal of timely tillage is to conduct tillage operations at optimal soil conditions to get desired soil–seedbed contact	• wait until proper soil moisture conditions exist • check soil moisture conditions to the depth of the planned tillage operation • use cover crops and crop rotation • vary the depth of tillage operations

BMPs FOR SOIL MANAGEMENT AND PROTECTION

FOR LIVESTOCK OPERATIONS

GREENHOUSE GAS BMP	BENEFITS FOR EMISSION REDUCTION	DESCRIPTION	TIPS TO MAXIMIZE BENEFITS
MANURE ADDITIONS	**Moderate C addition** • reduces N fertilizer **Reduced N_2O loss** • improves soil quality • reduces nitrate leaching	• liquid or solid livestock manures added before establishment, as side-dress or following field crop • manure can be broadcast, injected or banded	• develop and follow a nutrient management plan • test soil and manure • look for SOC-deficient soils • apply rates for crop uptake and soil building • incorporate to reduce loss • don't winter spread

Application of animal manures can substantially increase soil organic carbon levels. For example, increases of 45% in SOC have been shown on a Quebec corn–wheat–barley rotation after 18 years of manure application.

GREENHOUSE GAS BMP	BENEFITS FOR EMISSION REDUCTION	DESCRIPTION	TIPS TO MAXIMIZE BENEFITS
NON-MANURE ADDITIONS, e.g., BIOSOLIDS	**Moderate C addition** • reduces N fertilizer **Reduced N_2O loss** • improves soil quality • can reduce nitrate leaching	• additions of biosolids such as sewage biosolids, pulp and paper organic wastes, composts and food processing wastes will add considerable amounts of SOC • in most cases, application practices for biosolids are similar to manure	• see tips above for manure • ensure material analysis test results are available and used • follow guidelines and standards for separation distances and timing
DRAINAGE	**Reduced SOC loss** **Reduced CH_4 losses** • reduces denitrification • reduces runoff • reduces erosion • improves productivity	• excess soil water is removed from field using surface or subsurface drainage features • tile drainage (one of the most common forms) is established at prescribed depths and spacings to transfer water safely to a proper outlet	• don't use drainage systems as waste disposal systems • should be part of a soil and water conservation system to convey surface water as well • use surface inlets to reduce temporary ponding

Improved soil drainage, including tile drainage with surface inlets to reduce ponding, helps to reduce the incidence of anaerobic conditions that can lead to methane and N_2O emissions.

FOR LIVESTOCK OPERATIONS

GREENHOUSE GAS BMP	BENEFITS FOR EMISSION REDUCTION	DESCRIPTION	TIPS TO MAXIMIZE BENEFITS
REDUCED TRAFFIC	**Reduced CH_4 losses** • reduces denitrification • reduces runoff • reduces erosion • improves productivity	• less traffic means less compaction and reduced anaerobic conditions • in livestock operations, manure transportation and livestock access are most common traffic sources	• restrict traffic to farm lanes and tramlines whenever possible • remember that grassed headlands will lessen the impact of field operations • reduce tillage to help reduce traffic during moist soil conditions
	**Better-timed operations and reduced passes can reduce soil compaction. This in turn improves aeration, helping to lower greenhouse gas emissions.**		
SOIL CONSERVATION PRACTICES (e.g., STRIP CROPPING)	**Reduced SOC loss** • reduces runoff • reduces erosion • improves productivity	• contour cropping and strip cropping are examples of conservation practices • they are intended to control erosion by reducing the effect of slope and increasing soil cover • they can reduce erosion rates by up to 90% when combined with soil management BMPs	• incorporate them into an overall soil and water conservation system • use as opportunity for permanent cover, diversified crop rotation and further opportunities for manure application
EROSION CONTROL STRUCTURES	**Reduced SOC loss** **Reduced CH_4 losses** • reduces denitrification • reduces runoff • reduces erosion • improves productivity	• erosion control structures such as grassed waterways and sediment control basins reduce erosion by reducing the energy of flowing surface water on cropland and reducing the effect of slope	• design as part of drainage and soil conservation system • use as opportunity for permanent cover for improved carbon sequestration and increased nitrate uptake
	**Soil erosion control structures, as part of a cropland soil and water conservation system, can manage surface runoff and reduce the effect of slope on the potential of soil erosion.**		

LIVESTOCK AND NATURAL AREAS

BMPs TO REDUCE EMISSIONS AND IMPROVE SEQUESTRATION

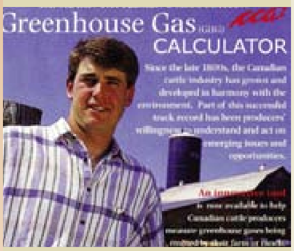
FOR LIVESTOCK OPERATIONS

GREENHOUSE GAS BMP	BENEFITS FOR EMISSION REDUCTION	DESCRIPTION	TIPS TO MAXIMIZE BENEFITS
WETLANDS (MARSHES, SWAMPS, BOGS AND FENS)	**High C addition** • high nitrate use **Reduced N_2O loss** • habitat benefits • water storage and supply benefits	• greenhouse gas source: organic soils and saturated conditions in wetlands • greenhouse gas sink: for carbon sequestration and assimilation of nitrates into vegetation • overall, wetlands are net sinks, but if drained are net sources	• avoid physical damage to soils, waterways and vegetation • prevent any deleterious substances from entering the wetland • seek approvals and permits if you plan any changes • harvest on a sustainable basis – ensure a long-term supply with minimal impact on habitat • don't graze wetlands
WOODLANDS	**High C addition** • high nitrate use **Reduced N_2O loss** • habitat benefits	• soil and trees are the best on-farm sinks for carbon • undisturbed forest soils and long-living, valuable woodland trees keep carbon out of the atmosphere more effectively than any other component in the farm landscape	• practise sustainable forest management • create a suitable environment for the growth of the most valued and highest quality tree species, while integrating the benefits of other resources (wildlife, soil and water conservation, renewable energy sources)
	**The primary production goal of forest management is to create an environment for growth of the most valued and highest quality tree species.**		
RIPARIAN AREAS	**High C addition** • high nitrate use **Reduced N_2O loss** • habitat benefits • water storage	• river and stream valleys and floodplains, lakeshores and areas around ponds may be considered riparian areas • managed or unmanaged, riparian areas have many environmental benefits	• avoid physical damage to banks, soils, waterways and vegetation • prevent any deleterious substances from entering – minimize grazing impact • maintain separation distances for nutrient and pesticide application
	**High-density livestock access will impede the ability of a riparian area to meet its greenhouse gas-reduction potential. It can also degrade soil, water and wildlife habitat. Check with your regional environmental authority for any restrictions on cattle access.**		

FOR LIVESTOCK OPERATIONS

GREENHOUSE GAS BMP	BENEFITS FOR EMISSION REDUCTION	DESCRIPTION	TIPS TO MAXIMIZE BENEFITS
BUFFER STRIPS	**High C addition** • high nitrate use **Reduced N_2O loss** • habitat benefits	• buffer strips are permanent grass borders on field boundaries, along watercourses or other natural areas • properly designed, they function as a last defence for soil and water conservation measures as well as important edge habitat for fish and wildlife	• buffer strips are effective against sheet and small rill flow but not intended for runoff as concentrated flows (large rills and small gullies) – treed is better • trees trap surface pollutants, trap nitrates in groundwater, shade surface waters and act as a barrier for farm traffic • remember that fenced is better – livestock can cause excessive damage to ditchbanks, watercourses and wetlands
WINDBREAKS AND SHELTERBELTS	**Moderate C additions** • moderate N use • habitat benefits	• these are rows of trees – evergreens, deciduous or both – planted along the edge of fields • windbreaks range in width from 1 to 5 rows • shelterbelts are greater than 5 rows	• plant at right angles to the prevailing wind where possible • locate windbreaks for maximum protection – predict probable mature tree height to determine optimal spacing between windbreaks • consider multiple rows for easier establishment and maintenance
RETIREMENT OF FRAGILE LANDS	**Moderate C additions** • moderate N use • less methane production • habitat benefits	• retirement means changing the land use of low-yielding and/or environmentally sensitive cropland	• usually involves planting of permanent cover of trees (reforestation), shrubs, herbs and grasses • use woody plants to sequester more carbon per unit area than than grass species and for a longer period • match species to site conditions and to greenhouse gas goals • fast-growing trees will fix carbon more quickly but more valuable trees will keep the carbon sequestered longer

Treed buffer strips will sequester more carbon and trap more soluble nitrogen than grass-based buffer strips.



This innovative tool is now available on compact disk to help Canadian cattle producers measure greenhouse gases being emitted by their farm or ranch. For a free copy, email feedback@cattle.ca or phone the Ontario Cattlemen's Association at 519-824-0334.

For More Information

BEST MANAGEMENT PRACTICES SERIES

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Buffer Strips, 2004

Manure Management, 2005

Nutrient Management Planning, 2006

Additional BMP titles (1991–1998), including: *Field Crop Production, Farm Forestry and Habitat Management, No-Till: Making it Work, Nutrient Management,* and *Soil Management.*

CANADIAN CATTLEMEN'S ASSOCIATION

Canadian Cattlemen's Association has several information sheets about management practices as they pertain to greenhouse gas emissions from beef operations. These are:

Greenhouse Gas Emissions; Manure Management and Its Impact on Greenhouse Gas Emissions; Pasture Lands Help Balance Greenhouse Gas Emissions; Reducing Greenhouse Gas Emissions through "Feeding and Breeding"; Grazing Tips; Rotational Tips; Sequestering Carbon.

Check out CCA's Greenhouse Gas Calculator available from CCA and most provincial Cattlemen's Associations. For further information, visit the CCA website at www.cattle.ca and click on the "Environment and Stewardship" link.

ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

OMAFRA has a series of four infosheets that address greenhouse gas emissions and their implications for farmers:

Infosheet #1 – *Greenhouse Gas and Ontario Agriculture*
Infosheet #2 – *Carbon Sequestration and Ontario Agriculture*
Infosheet #3 – *On-Farm Nutrients and Greenhouse Gas Reduction Opportunities for Ontario Agriculture*
Infosheet #4 – *Modifying Production Systems to Reduce GHG Emissions*

OMAFRA has extensive reference information on livestock production systems and greenhouse mitigation. You can find factsheets on livestock genetics, livestock nutrition and housing, livestock health, nutrient management planning, manure management, soil fertility, soil management, pasture management and the management of natural areas.

For a full list of titles and information on how to obtain copies, please visit the publications section of the ministry's website at:

www.omafra.gov.on.ca/english/products/product.html

If you do not have access to the Internet, please visit your nearest ministry office or call the ministry toll-free at 1-888-466-2372.

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