NUTRIENTS AND THE ENVIRONMENT

Your efforts to manage nutrients should be all about efficiency: ensuring your crops' needs are being met in a timely manner for optimal growth and yields, and minimized input costs. Of course, efficiency is also important for environmental protection.

Agriculture is one of the sources of nitrogen and phosphorus pollution of water in rural areas. Crop nutrients leaving farmland can pollute water. Nitrate-nitrogen can leach into groundwater. Phosphates, bound to soil particles, can run off land to surface waters such as drainage ditches, streams, and rivers. Concentrations of these nutrients in water above tolerable limits can be harmful to humans, livestock, and wildlife.

This chapter sets out the environmental implications of unmanaged nutrients, to give you a general idea of why and where they are of societal concern. We hope this provides a helpful context for the next chapter, which takes a magnifying glass to the basics of nutrient chemistry.

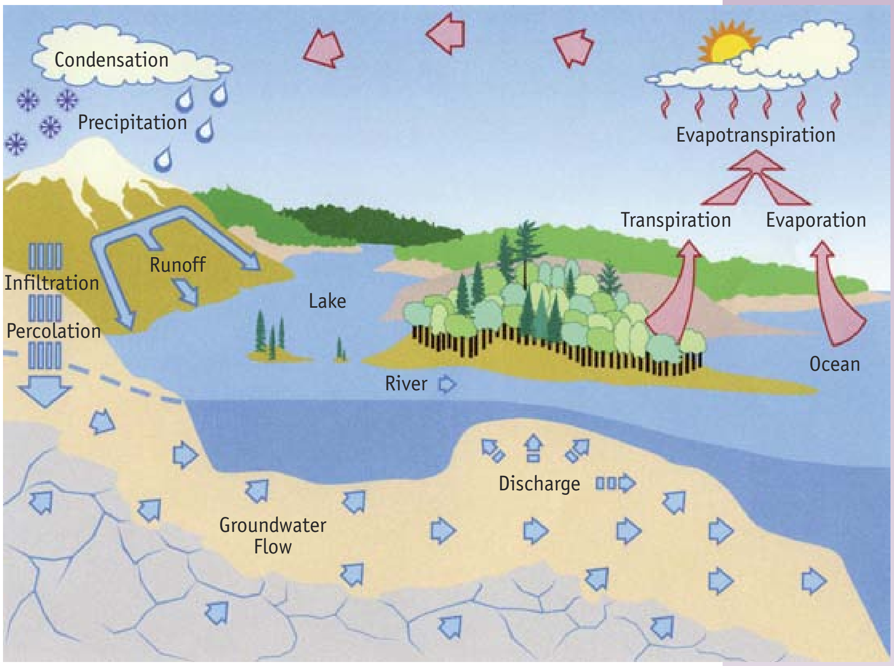
PHOSPHORUS (P) AND WATER QUALITY

Runoff to surface water or percolation into groundwater can carry nutrients if they are not carefully managed.

In unpolluted fresh waters, aquatic plant growth, including algae, is limited by the low level of phosphorus. When phosphorus is added to water, more algae are able to grow.

In past decades, abundant algal growth has made the water in some lakes and rivers in Ontario unsuitable for drinking or swimming. It has also led to the death of fish and other aquatic animals from lack of oxygen in the water.

During the second half of the last century, phosphorus was a major pollutant in the Great Lakes–St. Lawrence River watershed. Phosphorus pollution came from many sources in urban areas, mainly effluent from sewage treatment plants, storm sewers, and industrial sources. Most of these were point sources (i.e., easy to locate).



In rural areas, the sources of pollution have been effluent from sewage treatment plants in small towns, improper septic systems, storm sewers, manure runoff, cropland nutrient runoff, milking centre washwater, and eroded soil. Most of these are non-point sources (i.e., harder to pinpoint).

The risk of contaminating surface water rises when nutrients are managed inappropriately. Soil erosion and nutrient runoff can cause excess algal growth and a decrease in oxygen in surface waters, which degrade water quality for drinking, recreation, and fish habitat.

Due to efforts aimed at reducing phosphorus inputs to surface waters, it's no longer the threat to the Great Lakes that it was 20 years ago. Although portions of Lake Erie still have concentrations higher than desired, some locations are actually experiencing phosphorus concentrations that are lower than optimal for sustainable aquatic ecosystems. This is partly due to the removal of phosphorus from the aquatic system by zebra mussels.

Phosphorus loading to surface water is still an issue in small streams and tributaries, where excess algal growth can impact water quality habitat.

The invasion of exotic species like this zebra mussel has contributed to the reduction of nutrients in the waters of the Great Lakes.

Since 2000, areas in the Great Lakes have been identified as lacking in adequate nutrients such as phosphorus for healthy aquatic habitats.

Rural non-point sources of phosphorus contributed to excess algal and aquatic plant growth in parts of the Great Lakes.

Unchecked cropland runoff can lead to the pollution of surface waters.

Manure runoff can contaminate surface waters and drinking water supplies.

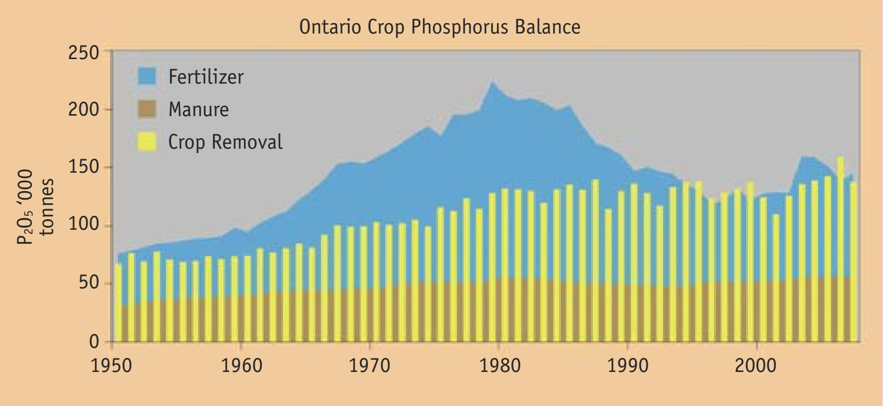
Elevated phosphorus concentration in rural area surface waters has three sources:

- **faulty septic systems near surface water**
- **farmsteads with improperly stored manure and washwaters**
- **eroding cropland with phosphorus attached to soil particles.**

Cropland soil conservation practices (e.g., reduced tillage) and erosion control structures (e.g., grassed waterways) will help to reduce erosion, runoff, and phosphorus loadings from cropland.

Manure storages can be designed to capture all contaminated liquids from livestock facilities and store them to prevent runoff.

Ontario Crop Phosphorus (P) Balance

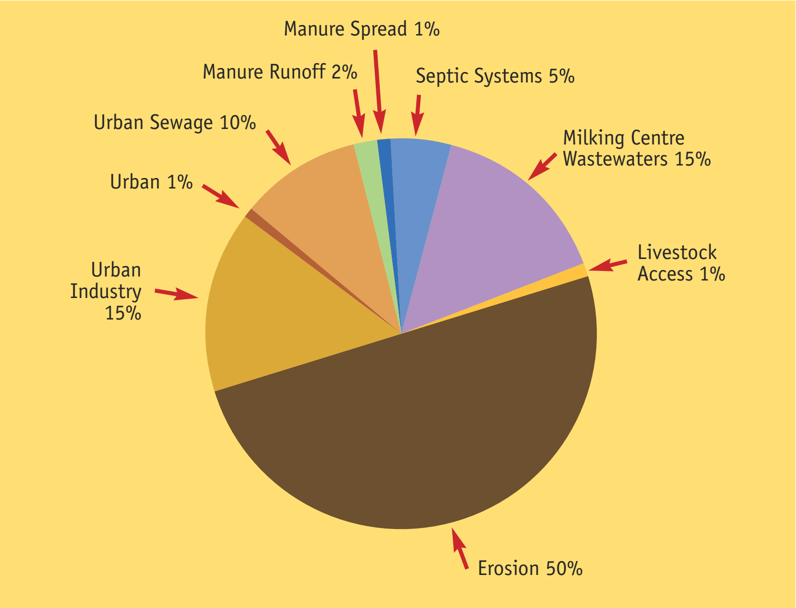


Use of nutrients in crop production has changed over time. These changes have had a profound effect on soil fertility, crop production, management practices and off-farm impacts. The accompanying graph illustrates an estimate of crop phosphorus removal as it relates to total crop inputs for the period 1950–2007. The inputs include commercial fertilizers and recoverable manures from cattle, swine and poultry.

Between 1950 and 1980, applications of P fertilizer increased more than three-fold. In most cases, P applications were increased to build up deficiencies in soil test levels. Some soils, however, were built up more than others. Crops like potatoes and tobacco tend to require high rates of P to boost soil test levels.

Since 1980, P fertilizer use has decreased to levels similar to the 1960s. Where soil P levels have been built up, lower rates of application suffice to provide optimum P nutrition for most crops. Moreover, improved soil and water conservation management has reduced P loss from Ontario cropland. Today, P additions and removals are much closer to balanced than a few decades ago.

Source: International Plant Nutrition Institute



Below are sources for phosphorus loadings to a typical Ontario watershed, from the greatest contributor to the least:

- **cropland runoff**
- **urban industry**
- **milking centre wastewaters**
- **urban sewage**
- **septic systems**
- **manure runoff**
- **applied manure**
- **livestock access.**

Source: Fanshawe Reservoir Clean Up Rural Beaches Study

NITROGEN (N) AND WATER QUALITY

Nitrogen exists in many forms in agricultural soils. Some forms, such as organic nitrogen and ammonium, are tied up in the soil and relatively unavailable to impact water quality. Nitrate (NO_3^-) and ammonia (NH_3) are the two forms considered to have an impact on water quality.

There are three main sources of nitrogen pollution in rural areas:

- septic systems
  - nitrate and ammonium from household and human wastes can contaminate groundwater and surface water
- livestock wastes
  - nitrate and ammonium-nitrogen from improperly handled, stored, or applied manure can run off to surface water or infiltrate soils and leach to groundwater resources
- cropland
  - nitrate and ammonium from commercial fertilizers and manures can run off to surface water through tile drains or leach into groundwater
  - nitrogen released from forage legume residues as they break down can leach into groundwater if fertilizer applications are not reduced to account for this.

The amount of nitrate that can leach into groundwater depends on the:

- amount of water draining through the soil
- amount of nitrate-nitrogen in the soil
- type of soil materials – permeable soils like sands or gravels are more prone to leaching.

Excess nitrate-nitrogen in the soil – from fertilizer, livestock manures, or legume plowdown crops – can make groundwater unsafe to drink.

Nitrogen in the ammonia form is very toxic to fish. Contamination of watercourses with materials containing large amounts of ammonia, such as liquid manure, can kill large numbers of fish.

Nitrate in groundwater is a concern because rural families depend on private wells for their water supply. Consuming water with high nitrate concentrations can cause illness, especially in infants, and reduce livestock performance. The maximum concentration of nitrate-nitrogen allowed under the Ontario Drinking Water Standard is 10 mg/L.

During 1991–1992, the Ontario Farm Groundwater Quality Survey tested 1,292 rural wells. Of these, 13.8% had nitrate-nitrogen concentrations greater than 10 mg/L. Shallow wells were more likely than drilled wells to have higher concentrations.

Young mammals are susceptible to health effects of high-nitrate drinking water.

When manure is applied after the growing season on fields with a high water table, or with bedrock close to the surface, nitrate may leach.

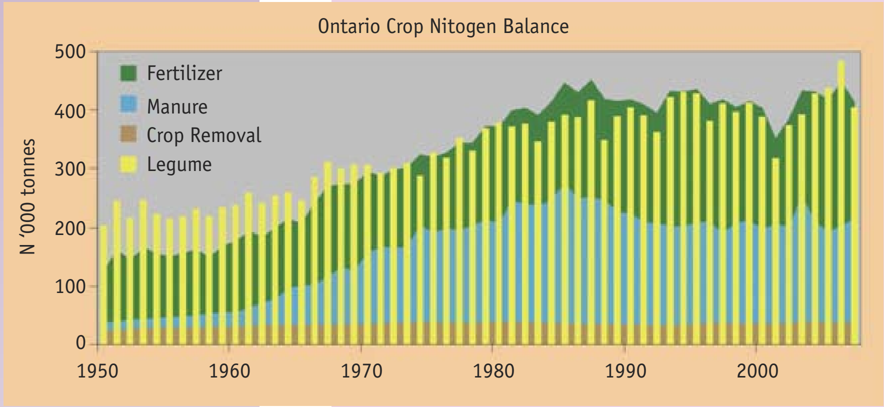
You run the risk of high levels of residual soil nitrogen if, during the growing season, more nitrogen is applied than removed.

Adopting BMPs for application timing and rates will reduce the risk of nitrate loss to shallow aquifers.

Cover crops can be sown following harvest of high N-use crops to "trap" nitrates for release during the next growing season.

Ontario Crop Nitrogen (N) Balance

Like phosphorus, the use of nitrogen in crop production has changed over time. The accompanying graph provides an estimate of Ontario crop nitrogen removal as it relates to total crop inputs for the period 1950–2007. The inputs include N-fixation by legumes, commercial fertilizers, and recoverable manures from cattle, swine and poultry.



Crop removal and legume N-fixation have both nearly doubled since the 1950s, due to improved land management, genetic improvement, and higher yields. Inputs of N from applied manure increased by about 40%.

The real story is with the use of commercial fertilizer N and the interaction with crop removal. Fertilizer N use increased 12-fold from the mid-1950s to its peak in the mid-1980s. Up to 1970, crop removal still exceeded N additions. From then to the early 1990s, the amount of N applied exceeded removal somewhat. But in the past 15 years, what's applied and what's removed is much closer to balancing. That's good news for agriculture and water quality.

Source: International Plant Nutrition Institute

GREENHOUSE GAS EMISSIONS AND CROP NUTRIENTS

Climate change is linked to the emission of greenhouse gases such as carbon dioxide, methane and nitrous oxides. While some greenhouse gases are naturally occurring, increased levels of emissions are of mounting concern. Global temperatures have risen 0.74 °C over the past century, and this warming is thought to be related to elevated greenhouse gas levels.

Denitrification is the conversion of nitrate to nitrogen (N_2) gas. It's a naturally occurring process in saturated soils.

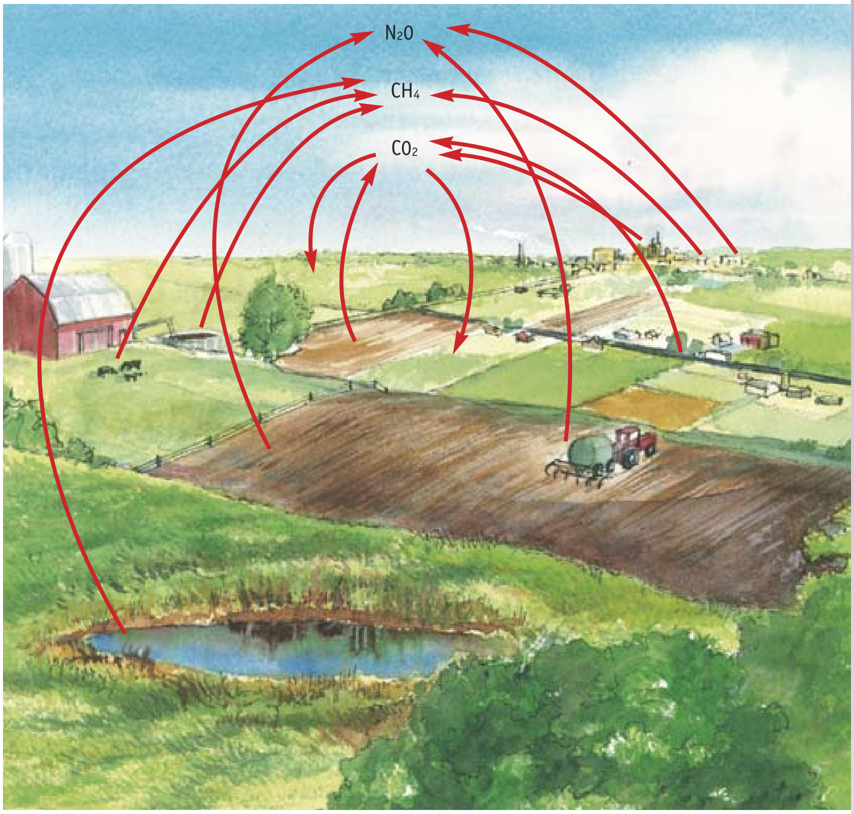
However, when conditions are wet or semi-saturated, the process is somewhat altered (less anaerobic) and nitrous oxide (N_2O) is formed. Nitrous oxide is the key greenhouse gas of concern from agriculture as its effect is 296 times more powerful than that of carbon dioxide.

The gases at issue are nitrous oxide, methane and carbon dioxide. The global warming potential of each compound, relative to carbon dioxide, follows this relationship:

carbon dioxide (CO_2) = 1
methane (CH_4) = 23
nitrous oxide (N_2O) = 296

In other words, nitrous oxide has 296 times more impact as a greenhouse gas than carbon dioxide.

In North America, agriculture is absorbing nearly as much carbon dioxide as it is emitting, and may even be a net sink for CO_2. Methane is emitted from the digestion of feed by ruminants, from manure storage, and from saturated soils, and accounts for about half the net emissions from agriculture. The other half of the net emissions is nitrous oxide. It is emitted sporadically, from soil and from manure storage.



NITROUS OXIDE FROM STORED MANURE

In Ontario, nitrous oxide (N_2O) appears to be the greenhouse gas component with the greatest opportunity for reductions.

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

Solid manures are mostly aerobic. However, anywhere in the pile where the manure materials are saturated, such as the bottom, nitrous oxide may be generated through partial denitrification.

The rate and extent of nitrous oxide emission from soil or stored manure depend on the concentration of oxygen in the soil or in stored manure, the amount of available N, and the amount of carbon.

NITROUS OXIDE FROM APPLIED MANURE AND FERTILIZER

N_2O fluxes can occur anytime the soil has saturated zones. Much of the nitrous oxide from cropland and manure is emitted during thawing conditions of late winter and early spring.

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 taken up by the plant, but most of it is converted to nitrate by nitrification. Nitrification of either manure or fertilizer ammonium can be one source of N_2O.

Nitrate N (NO_3^-) can be used by a crop or lost from the system by leaching, but some of it is vulnerable to denitrification to N_2O or N_2.

ORGANIC CROP NUTRIENTS AND PATHOGENS

A **pathogen** is any virus, bacterium or protozoa capable of causing infection or disease in animals or humans. Pathogens range from parasites such as roundworms, to bacterium such as *Salmonella* and *E. coli*, to protozoa such as *Cryptosporidium parvum* and *Giardia*. Most livestock viruses are not easily passed to humans.

Manure and other untreated organic nutrients come from biological sources, and as such, contain bacteria, viruses and parasites. The variety and numbers of these micro-organisms contribute to the beneficial role of manure as a soil amendment. However, some are referred to as pathogens because they can infect livestock and humans.

Pathogen Sources

Pathogens in the environment can come from many sources, such as:

- improperly constructed septic systems
- runoff from manure storage or spreading
- grazing animals
- companion animals
- wildlife.

Programs to reduce pathogens in surface water must address all these sources, but cannot be expected to eliminate pathogens entirely. Treating surface water before drinking it is a necessity!

Grazing animals can be a source of pathogens.

PATHOGEN SURVIVAL

Few pathogens survive for long when outside a host. Most last only a few days. But some can last up to several months, depending on a number of environmental conditions. The following can limit pathogen survival:

Improperly applied manure can be a source of pathogens.

- ► high temperatures, such as those reached during composting
- ► freezing or freeze/thaw cycle – whereas moderate temperatures can extend the lifespan of pathogens
- ► low humidity, sunshine and dry field conditions
- ► manure decomposition, which produces chemicals that kill some plant pathogens
- ► acidic soils – pathogens survive longer in neutral or alkaline soils
  - ▷ treating materials to raise the pH to high levels will also kill pathogens
- ► absence of oxygen – liquid manure and the wettest part of stored solid manure are considered anaerobic environments (i.e., no oxygen).

Soil can be effective at trapping bacteria and other organisms, filtering out most protozoa and bacteria. Soils with high organic matter and clay content are more effective at filtering viruses. However, pathogens can bypass soil filters by preferential flow through large macropores (cracks and earthworm burrows) to shallow aquifers or through to tile drainage systems.

Pathogens can move to surface water via surface runoff, or by livestock or wildlife accessing streams and creeks. Groundwater is less likely to be contaminated than surface water. For more information on pathogens and pathogen survival, please see the BMP book, *Manure Management.*

Pathogenic bacteria from organic nutrient sources may infect humans if there's a direct pathway to drinking water supplies or recreational waters. In water wells that have been contaminated through poor construction or management, these bacteria can be controlled with chlorine or UV treatment.

ORGANIC CROP NUTRIENTS AND AIR QUALITY

Organic sources of nutrients can be a source of air pollution and odour. Bedding and dry manure can add dust and other particulate matter to the atmosphere.

PRIMARY MANURE GASES

COMPOUND	DESCRIPTION
CARBON DIOXIDE	• odourless • generated by microbial activity (anaerobic* and aerobic)
METHANE	• odourless • generated by anaerobic activity
AMMONIA	• sharp, pungent, irritating odour • generated by anaerobic and aerobic activity • water-soluble and less dense than air • readily disperses in open environment, resulting in it being more of an odour concern within barns than during land application
HYDROGEN SULPHIDE AND RELATED SULPHUR-CONTAINING COMPOUNDS	• hydrogen sulphide can build up to toxic levels, particularly in confined spaces, causing rapid death to humans or animals • hydrogen sulphide gas possesses a powerful "rotten egg" fragrance produced during anaerobic decomposition of manure • water-soluble and heavier than air • humans can readily detect very low concentrations of such compounds
VOLATILE ORGANIC ACIDS	• wide variety of types and characteristics • mostly produced under anaerobic conditions • important contributors to manure odour
PHENOLICS	• highly odorous compounds • found in raw manure and increase under anaerobic conditions

* "anaerobic" means oxygen-deficient

The amount and type of gases produced depend on the type of manure, and the way it is handled. Aerobic conditions will generate gases such as carbon dioxide and nitrous oxide. Anaerobic conditions (liquid manure, the centre of solid piles) can generate hydrogen sulphide, ammonia and methane.

Some gases are often trapped within the bulk of the manure until the storage is disturbed for spreading. This makes the smell much worse at spreading time.

Manure odour is strongest during application. For the most part, odour-causing gases are trapped in stored manure.

Researchers have identified over 160 gaseous compounds that originate from manure.

ENERGY USE

Much of the cost of supplying nutrients stems from the energy required to manufacture, refine, transport, or apply them. Efficient use of nutrients helps reduce both the cost of crop production and the consumption of non-renewable resources.

Ensuring you're applying nutrients only when you need them will help reduce costs and energy consumption.