Chapter 10 Environmental impacts of nutrient use – Runoff, leaching, Minimizing impacts, Management – *Dr. Harold van Es, Cornell University*

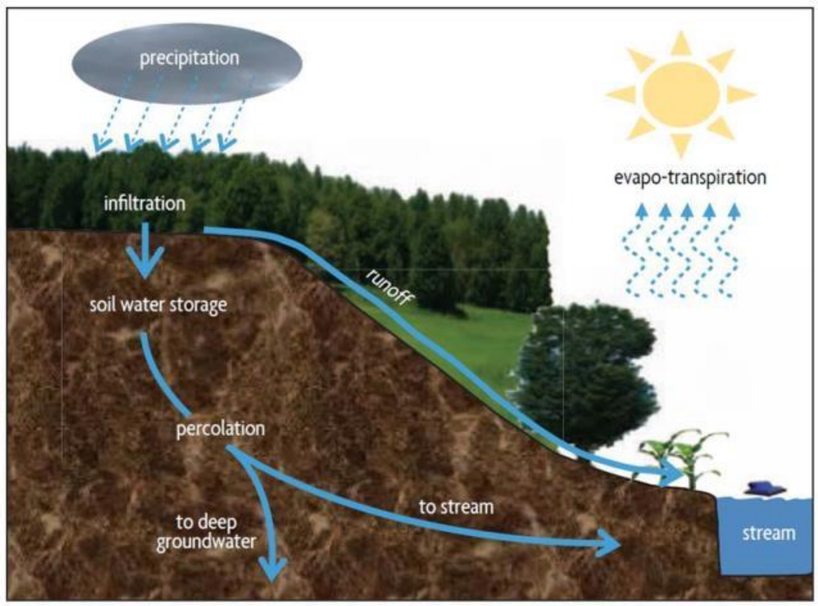
Introduction

It is important to note that most berry crop production is done in a way that is relatively sustainable and has relatively little environmental impact. Comparing berry crops with corn for example, we see most berries are produced on a smaller scale, are perennial vs. annual, require less nutrient inputs and less tillage. Their environmental impact is smaller then, yet still a matter of concern and something to be taken seriously.

Various soil components, when carried by excessive water events (i.e. precipitation) into water bodies, become contaminants, potentially causing serious damage to the ecosystems they enter. These are referred to as environmental losses. The 4 primary environmental losses to be concerned about with berry crop production are sediment, nitrogen, phosphorus and pesticides.

Environmental loss processes

Environmental losses occur when there is a lot of water in the soil system; this water comes mostly as precipitation and irrigation. That said it's the extreme precipitation events (1 to 2" or more of water at a time) that cause environmental losses to occur.



The basic hydrologic cycle

So what happens to precipitation when it reaches the land's surface? It basically goes in two directions (*right*). The water either infiltrates into soil or runs off. Water that runs off often takes sediment with it; this process is referred to as erosion. Soil nitrogen and/or phosphorus may also be carried off at the same time. These soil components, now contaminants, may then readily reach streams, lakes estuaries or other bodies of water where they cause problems.

If all the water infiltrates it is then held by the soil "sponge" and made available to plants through evapotranspiration. If there is excess water in the soil sponge it percolates further down either as shallower or deeper ground water. Shallow ground water may eventually reach a stream or other body of water. Chemicals may be carried off in the percolating water, a process referred to as leaching.

So to summarize, the environmental loss pathways discussed thus far include runoff (nitrogen, phosphorus, pesticides), erosion (all four contaminants), and leaching (nitrate and pesticides).

A fourth environmental loss process is that of gaseous losses which involve nitrous oxide and pesticides. Gaseous losses which involve nitrous oxide (denitrification) are not directly driven by water but are indirectly water driven.

When the soil becomes anaerobic (without air), nitrate is transformed to nitrous oxide, a greenhouse gas 300 times more potent than carbon dioxide.

Gaseous losses of pesticides are not water related. Instead these are related directly to the properties of the pesticide itself. Pesticide losses will not be discussed further as it is beyond the scope of this chapter.

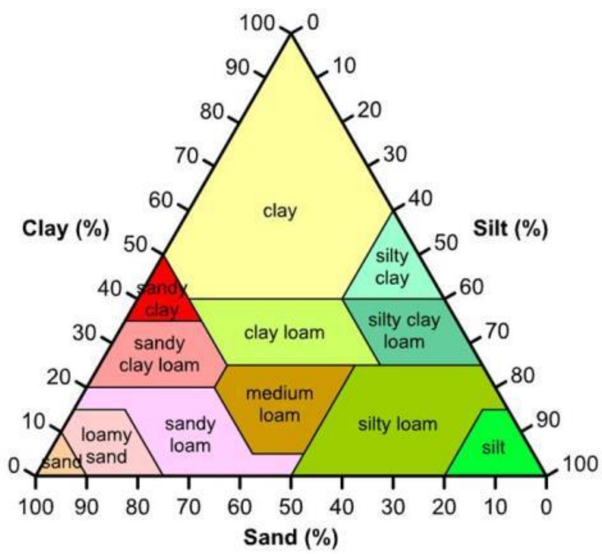
Environmental loss potential

The potential for environmental losses is affected by several factors; the first of these being weather. Intensive rainfall events bring with them higher potential for erosion; excess water also generates leaching.

Secondarily, inherent soil properties such as soil texture, organic matter and so on, affect where the water goes, and what it takes with it. This factor will be discussed in more detail later in the chapter. Thirdly, soil health is a factor. If soil health has been built up to where the soil has good aggregation, then environmental loss can be reduced significantly.

Finally, "real-time" soil management practices such as cultivation, soil cover, traffic, organic and inorganic fertilizer applications are also factors. Cultivation of soil exposes it to the elements, facilitating erosion. Soil cover, like mulch, reduces soil exposure and thus erosion. High traffic on soils causes compaction; this in turn leads to poor infiltration and runoff. Last but not least the amount of fertilizer applied, whether organic or inorganic, and where we place it is a significant factor. In principle, the more fertilizer applied the higher potential for losses.

Inherent properties of soil and how they affect the potential for environmental losses



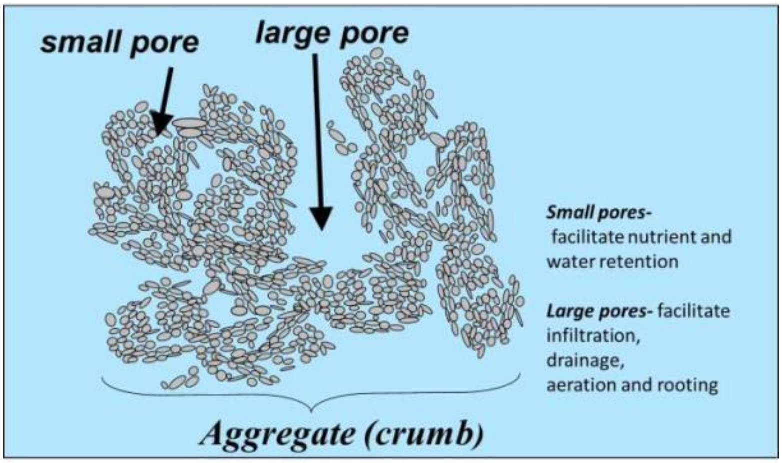
Soil texture or the distribution of soil particle sizes, in terms of sand, silt and clay, is the most fundamental inherent soil property. The textural triangle (*left*) provides the basis for a lot of these environmental loss considerations.

Soil particles and pores (texture) defines the basic structure of soil, what may be referred to as the soil "house". The structure of the house (walls, roof, and basement) comprises the most visible part of the house; in the soil these are the soil particles, or taken together, the soil aggregates or crumbs.

This is not necessarily the most interesting part of the soil house however, it's what happens in the soil spaces or "rooms" between the soil crumbs. These spaces are the soil pores where all of the processes take place (water and air movement), and where the organisms (bacteria, fungi) are, where the life is.

The relative quantity of the various sized pores — large, medium, small, very small — govern the important processes of water and air movement. In a sandy soil, most of the "rooms" or pores are relatively large (but in general terms still relatively small, less than 2 mm in most cases). These large pores (in terms of soil) will lose their water very quickly due to their weak capillary force. Conversely, clay soils mostly have small pores that retain water tightly (strong capillary force). If the clay soil is well-aggregated, it will have a few large pores in addition to the small ones. Figure 47 depicts an example of a soil aggregate or crumb with a range of pore sizes and their associated processes. Large pores facilitate infiltration, drainage, aeration and rooting. Small pores, because of their strong capillary force, facilitate both nutrient and water retention. So for example, when the concern is leaching, it's good to have small pores that retain nutrients in the soil.

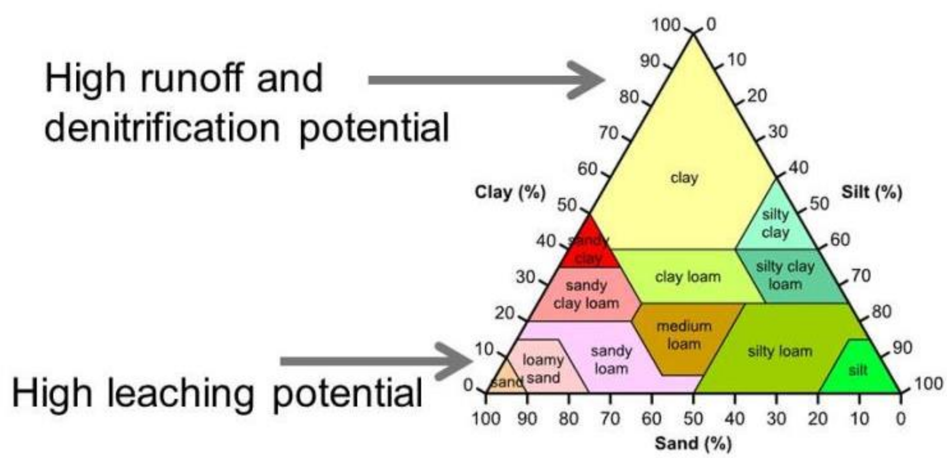
Figure 47. *Pore sizes and their associated processes.*



Quiz Yourself

1. Which soil has a higher leaching potential?
   a. Sand
   b. Silt
   c. Clay
2. Which soil has higher runoff and denitrification potential (gaseous losses of N)?
   a. Sand
   b. Silt
   c. Clay

Let's take another look at the textural triangle then in terms of loss potential. The more sandy soils i.e. sand, loamy sandy, sandy loam, sandy clay loam, etc. have higher leaching potential. The more clay soils i.e. clay, clay loam, silty clay, silty clay loam, etc. have higher runoff and denitrification potential.



Answers: Sand has the highest leaching potential because it has large pores that don't retain water and nutrients well; nutrients are easily washed out with the percolating water. A clay soil has the highest runoff potential with its small pores and lower infiltration capacity. Because clays are composed chiefly of small pores, aeration can often become a problem under excessive water conditions, causing denitrification (release of nitrous oxide).

Hydrologically sensitive areas, their characteristics and identification

Hydrologically sensitive areas are parts of the landscape that have high potential for pollutant losses. These areas are potentially sensitive to either surface runoff or leaching and subsurface recharge losses.

Potentially sensitive areas for surface runoff losses include flood plains, areas adjacent to flowing and standing water bodies, and areas with low infiltration capacity and saturated areas.

Most flood plains tend to have relatively coarse textured soils like gravels or sandy soils; these we would say have high infiltration capacity *but* because they are located near streams where heavy rains cause flooding they are sensitive to surface runoff and in this case, everything goes.

Similarly, areas adjacent to flowing or standing water tend to be hydrologically sensitive, as they tend to be wetter areas in the landscape and close to these water bodies; there is very little capacity for buffering or filtering out some of these contaminants in these adjacent areas.

Areas with low infiltration capacity are also a concern because the field soil itself has become compacted or the field is adjacent to another compacted area (i.e. road) where the runoff from this area causes runoff and erosion in the field. Saturated areas are already wet and so are subject to runoff as well.

Potential sensitive areas for leaching and subsurface recharge include: groundwater recharge areas near wells or springs and areas with permeable soils.

Groundwater recharge areas near wells or springs are areas that typically have very permeable soils; when you are close to these drinking water sources you need to be extra careful about minimizing/eliminating environmental losses in these areas. Other areas of very permeable soils are also of concern.

Soil survey reports, whether traditional map resources or on line resources such as the Web Soil Survey discussed in chapter 1, are valuable tools in identifying potentially hydrologically sensitive areas. They provide information on basic soil properties, suitability for use and environmental loss potential (runoff, erosion, leaching). The reports provide an excellent first look for evaluating this potential.

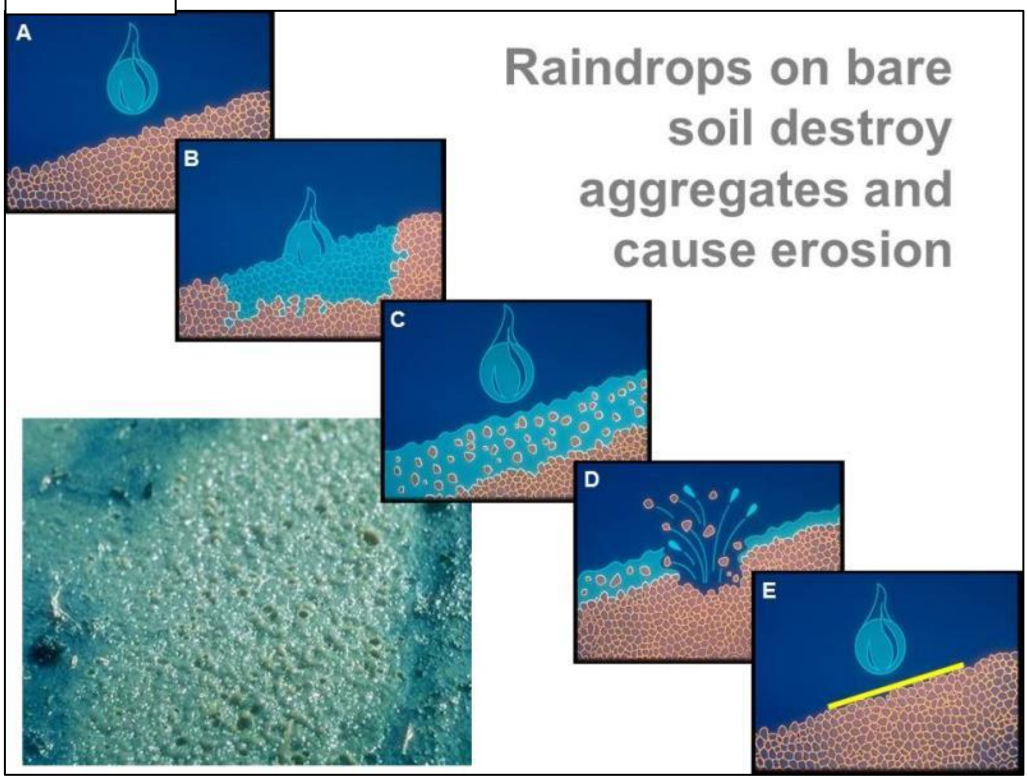
Erosion

Erosion has a 2-fold effect on the landscape. First, it removes surface soil which is highest in organic matter and most desirable for plant culture. What are left behind are the coarse gravelly fragments that are not as easily washed off by the runoff water (*above right*). The other effect of erosion is that the sediment that is washed away ends up somewhere else (*below right*), covering aquatic habitat, making water less potable (suitable for drinking) or les suitable for navigation. Both of these effects are highly undesirable; erosion remains a large problem in the United States.

A number of factors effect erosion including soil type, slope, soil health, and surface management. Soil textures with high runoff potential also have high erosion potential. Steeper slopes of course are of greater concern being subject to higher levels of erosion.

Soil health is another factor. If the soil is well aggregated, with good rooting that pumps the water out well, erosion potential is reduced. Surface management is yet another factor; whether the surface is kept covered, or exposed, the tillage methods used, herbicide use, all have a great influence on erosion potential.

Figure 48

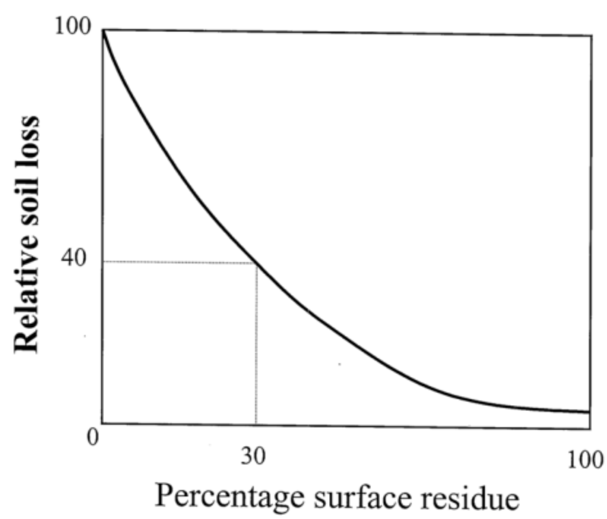


A falling raindrop has energy from its mass and velocity (*Figure 48a*). When it contacts a dry soil; the soil is hard and resilient and capable of absorbing the energy from that rain drop (*Figure 48b*).

As the soil begins to wet up it becomes softer and weaker. The raindrop energy cannot be absorbed as well; causing aggregates to be smashed and dispersed (*Figure 48c*). On a very soft soil you can actually see the impact of the raindrops (*Figure 48d and photo bottom left*). Water begins to accumulate at the surface and if the soil is on even a moderate slope you begin to initiate runoff and erosion.

Alternatively, raindrop energy maybe absorbed by a soil surface cover (*Figure 48e, represented by yellow line*) such as mulch, compost or other organic products which greatly reducing erosion potential.

The rather famous graph on the right shows erosion (relative soil loss) from zero to one hundred percent vs the percentage of surface residue.



If the soil is bare, the relative soil loss is 100%. That said there is a fairly rapid decrease of erosion losses with even modest amounts of surface residue. Thus with 30% surface residue, the relative soil loss is reduced about 60% from 100 to about 40. As you approach 100% surface residue erosions losses become minimal.

The best way to reduce erosion is to have the soil covered. The good news is that this management practice also has a lot of benefits in terms of building healthy soils, reducing the effects of extreme water and temperature conditions at the surface, and promoting biological activity. To some extent then, it's a no-brainer to put mulch or some other organic material on the soil surface.

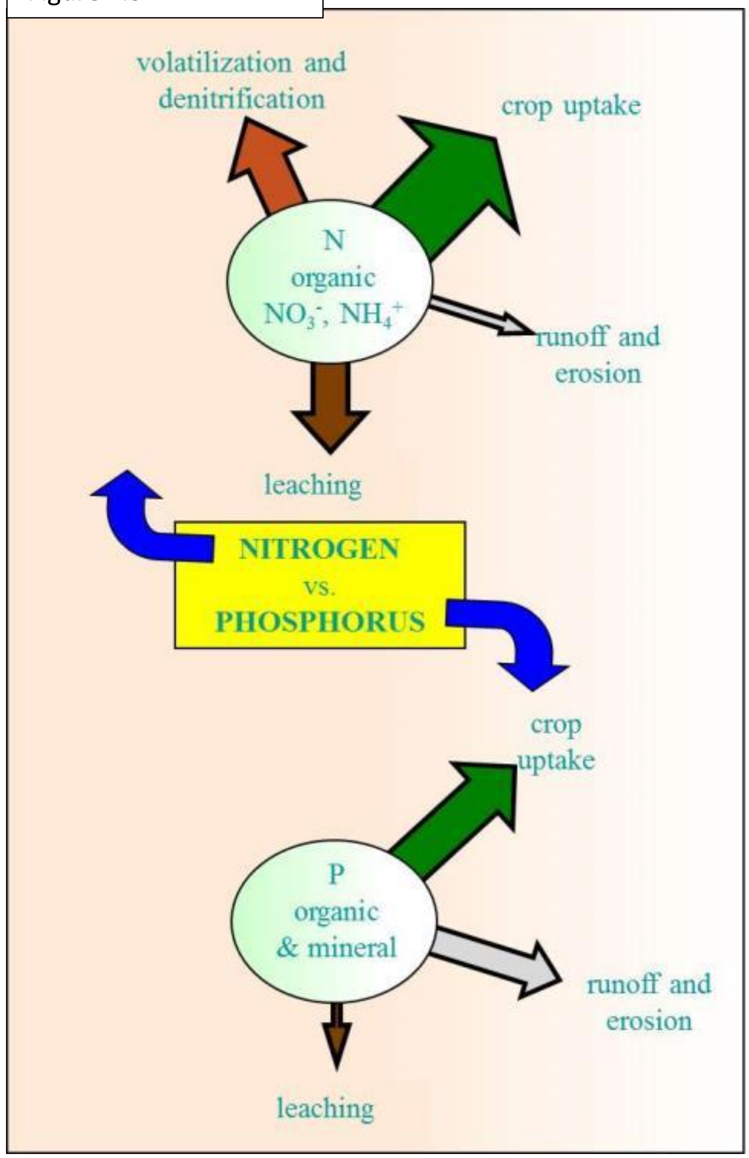
Erosion and runoff prevention

The main strategies then to avoid erosion and runoff then are 4-fold. First, if at all possible avoid fields that are prone to flooding or have high runoff potential. Second, keep soil covered with mulch, compost or crop residue as much as possible. Third, build and maintain soil health (aggregation, etc.) to increase infiltration capacity and reduce runoff potential. And finally, use grass alleyways between rows, preferably along the contour; this will infiltrate water quite well and filter out any sediment coming from the rows if they are unprotected. These practices are not difficult to implement and in fact are already in use by most berry growers.

Nutrient losses

The nine essential macronutrients for plants were discussed in previous chapters. By way of review, the first three of these, carbon, hydrogen and oxygen, are plentiful in the environment. Of the remaining six, nitrogen and phosphorus are the macronutrients that are applied in large quantities and are also of environmental concern. These two will be the focus of our discussion of environmental losses of nutrients.

Figure 49



The pictograph on the right shows different pathways for soil losses of nitrogen (*top*) and phosphorus (*bottom*); relative amounts lost are indicated by width of arrows.

Although N and P are both nutrients, they behave very differently in the soil and they have very different impacts. Each one will be discussed in more detail.

Nitrogen can be in the soil in both organic and inorganic forms as nitrate and ammonium. Most of the nitrogen present we hope will be taken up by the crop, promoting good growth; that's the objective. Nitrogen may run off or erode but typically these are relatively insignificant loss pathways; volatilization and denitrification are the primary loss pathways for nitrogen. Both of these processes are initiated by very wet soil conditions.

Phosphorus, on the other hand, can be in the soil in organic or mineral form. Again the desired pathway of phosphorus in the soil is crop uptake of course. Leaching is only a problem in some very rare cases where there are excessive amounts of phosphorus in the soil, in combination with sandy soils and very shallow water tables. In most cases, runoff and erosion are the primary loss pathways for phosphorus.

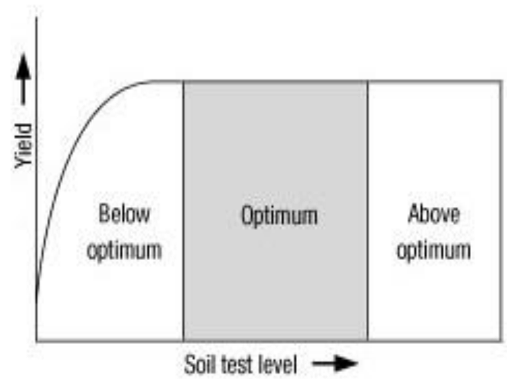
Managing phosphorus for reduced losses

Look again at the bottom half of the pictogram above, which focuses on phosphorus loss pathways. Primarily runoff and erosion are the concerns here.

Phosphorus, as we have learned, is a necessary nutrient for plants to live; it is also a limiting factor for aquatic plant growth in many freshwater ecosystems. Most fresh water lakes in North America are phosphorus limited. It actually takes relatively little phosphorus to induce eutrophication, a situation where excessive aquatic plant growth and decay occurs. Eutrophication is a natural process to some extent accelerated by phosphorus entering water systems form farms. Eutrophication favors growth of algae and phytoplankton over the more complex aquatic plants. As the algae die they sink to the bottom where they are decomposed by bacteria. This decomposition process uses oxygen; depriving deeper waters of oxygen, sometimes killing fish and other organisms. Moreover, eutrophication decreases the value of lakes and rivers for aesthetic enjoyment; health issues may ensure where eutrophication causes complications with drinking water treatment.

The photo at the right shows a Canadian lake with a barrier in between; one side of the lake received phosphorus inputs, the other side did not.

Berry farms are not likely a huge contributor to this problem but they could contribute as a consequence of poor management practices.



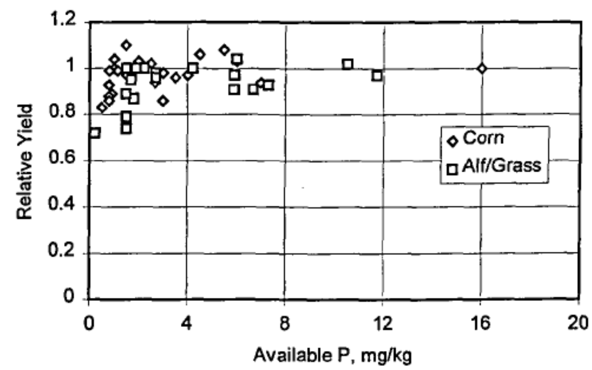
Practices that reduce runoff and erosion also reduce phosphorus losses also; things like surface mulches and improved infiltration capacity through good soil health management, etc.

There is another dimension to this however, basically, the accumulation of phosphorus in the soil. Lots and lots of phosphorus in soil increases loss potential, an additional concern.

Soil tests and phosphorus

Chemical extraction of nutrients provides a general estimate of crop nutrient availability; generally these estimates are low precision, but ranges of deficiencies and excesses are well defined.

This hypothetical graph gives us an idea of what happens to yield as phosphorus in soil increases (*top right*). In terms of soil tests, where we measure soil phosphorus on a regular basis, we know where phosphorus is very low, reduction in yield occurs and there is benefit to phosphorus addition. There is a point where there is sufficient phosphorus in the soil for good crop production; an optimum range where little if any additional benefit is realized from P input. Above that optimal range is excess, where not only are no additional benefits realized from inputs, but also there is cause for concern in regard to phosphorus loss through runoff and erosion.



The bottom graph provides real data on the relationship between relative yield and amount of available soil P for corn and alfalfa/grass. Looking at the data, for Morgan extractable P, in the range from 4 to 6 is about where the cut-off is for going from below optimum to optimum; there's no yield increase beyond that. And again at some point beyond 6 you reach excess levels.

Although the response to P levels is often quite variable and low precision, there is really strong agreement that there is a soil P level that is sufficient, not deficient, and not excessive.

The use of different chemical extractants gives slightly different results in terms of phosphorus extraction (*right*). Some extract a little bit more, some extract a little bit less, depending on the method used. It follows then that each extractant has its own set of ranges for low, optimum, high and very high. It's the very high range where we need to be concerned about excessive phosphorus. We want to keep these very high levels from happening in soil as much as possible.

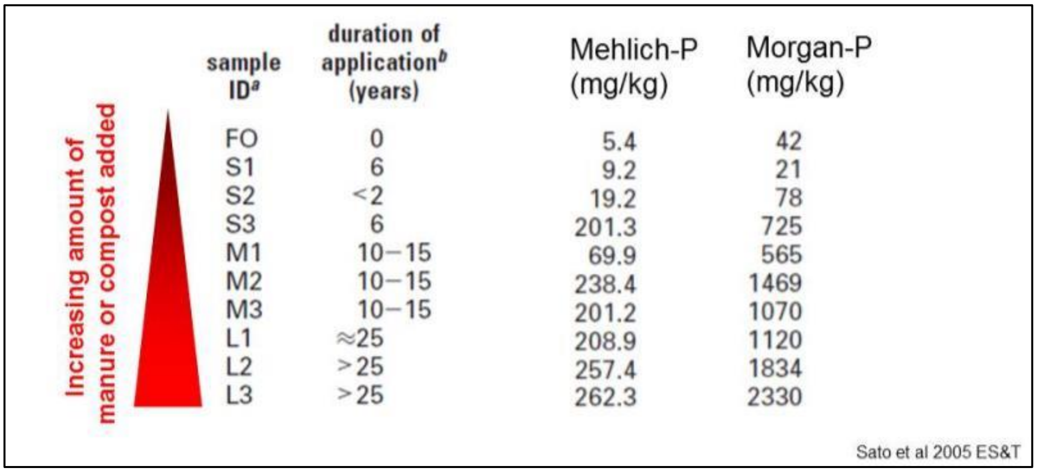
Interpretation Ranges for Different P Soil Tests

	Low	Optimum	High	Very High
Olsen	0–7	7–15	15–21	>21
Morgan	0–4	4–7	7–20	>20
Bray 1 (Bray P-1)	0–15	15–24	24–31	>31
Mehlich 1	0–25	25–50		>50
Mehlich 3	0–15	15–31	24–31	>31
AB-DTPA (for irrigated crops)	0–7	8–11	12–15	>15

Note: Units are in parts per million phosphorus (ppm P), and ranges used for recommendations may vary from state to state.

In most cases, if a grower regularly soil tests and is careful about how much they apply, problems of this nature generally do not occur. Cases were these excessively high levels do occur are those where a lot of organic inputs have been made. This is sometimes the case with manures, on dairy farms for example, with repeated applications causing P build up in soil. Another instance of this is on organic farms with repeated applications of compost. Both manures and composts are not as well-balanced in terms of nitrogen and phosphorus; that is, you typically apply too much phosphorus for what the crop needs when you apply the right amount of needed nitrogen. When this scenario plays out year after year, significant buildup of phosphorus levels can occur. *Figure 49* provides real life examples and test results below showing how phosphorus can accumulate with repeated applications of compost or manure.

Figure 49. *Accumulation of phosphorus in soils with organic matter additions.*

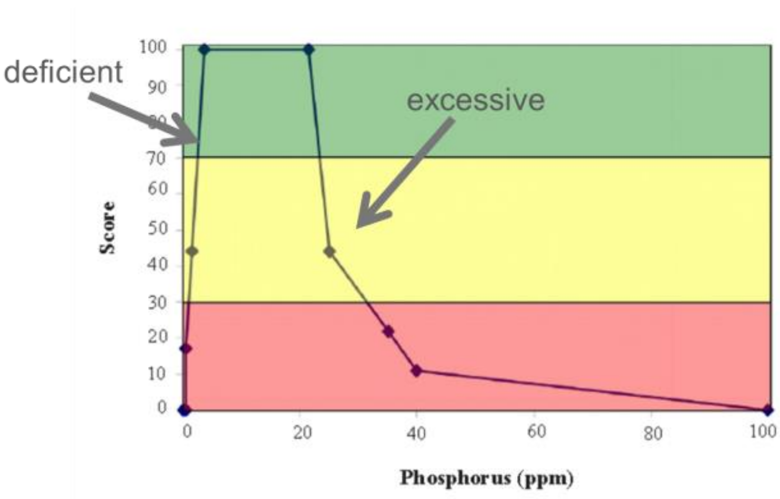


Increasing amount of manure or compost added

sample ID[a]	duration of application[b] (years)	Mehlich-P (mg/kg)	Morgan-P (mg/kg)
FO	0	5.4	42
S1	6	9.2	21
S2	<2	19.2	78
S3	6	201.3	725
M1	10−15	69.9	565
M2	10−15	238.4	1469
M3	10−15	201.2	1070
L1	≈25	208.9	1120
L2	>25	257.4	1834
L3	>25	262.3	2330

Sato et al 2005 ES&T

Once an excessive level as soil phosphorus has been reached then you need to change your soil "diet" or how you add nitrogen to the soil. You might add clover or alfalfa residue, for example, if you are an organic grower of if not, a nitrogen fertilizer and smaller amount of compost to start reducing those phosphorus levels in soil.



The Cornell soil health test accounts for this in terms of the scoring curve used for phosphorus analysis (*left*). The actual value of a soil health indicator, phosphorus, is interpreted on a scale from 0 to 100. Very low P levels receive a low score; as P increases the score increases as well. Four to six is the optimal level; then it is down-scored as levels reach excess.

To summarize, there are 5 main strategies for reducing phosphorus losses. The first four are the same as those for minimizing runoff and erosion prevention. These include: avoid locations with high flooding or runoff potentials; keep soil covered with mulch or residue; build and maintain soil health (aggregation, etc.) to increase infiltration capacity and reduce runoff potential, and maintain grass alleyways (preferable along contour). The fifth additional strategy is to monitor soil P levels and use management practices that help to avoid reaching excessive phosphorus levels in soil.

These five management strategies are very effective for reducing phosphorus losses from soil.

Managing nitrogen for reduced losses

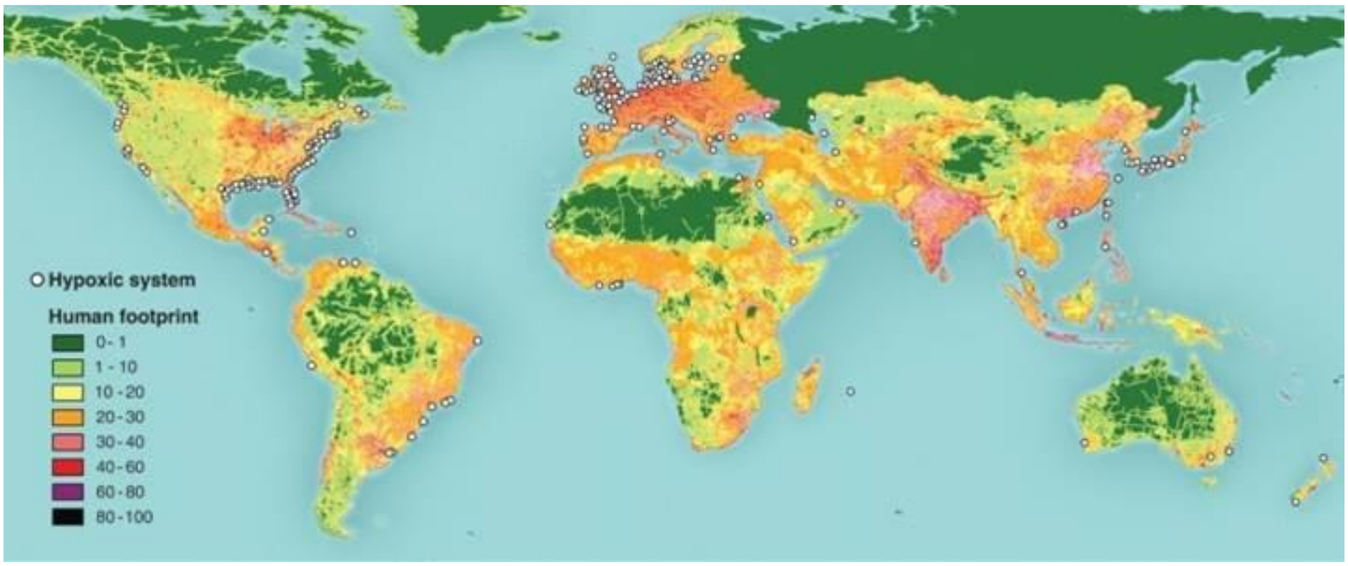
Nitrogen is a very complex element in the soil, both in terms of how it behaves in soil and also in terms of the larger considerations around nitrogen. There are currently a number of concerns in regard to nitrogen.

The first concern is the high energy consumption for the Haber-Bosch industrial process that takes atmospheric nitrogen to reactive nitrogen. It requires a lot of natural gas, a lot of energy, and generates a lot of carbon dioxide.

Secondly there is a persisting concern about ground water nitrate levels. There hasn't really been any improvement in general in these levels over the past couple of decades. This lack of improvement results in large part from over application of nitrogen, particularly in sandy locations, even urban areas (i.e. lawns, golf courses, etc.)

A third concern is the loss of nitrogen into rivers and streams and then into estuaries causing hypoxia/anoxia (low oxygen levels resulting in fish kill). Figure 50 below shows about 300 locations around the world where there are concerns with high levels of nitrogen in estuaries causing hypoxia/anoxia (low oxygen levels/fish kill). One area where this is well known in Northwestern Europe where there is a lot of nitrogen use, a lot of intensive dairying. This are is the original area where dairying was developed.

Figure 50. *The nitrogen problem (from: Diaz and Rosenberg, 2008)*



In North America, the area along the east coast from southern New England down to Florida and then along the Gulf coast where we have probably the largest problem with all of the nitrogen that comes out of the Mississippi river basin. This nitrogen is associated primarily with corn production.

These are often very important estuaries, for example the Peconic Bay on Long Island, where there are a lot of concerns, even from horticultural farms about trying to reduce nitrogen losses.

The fourth area of concern is greenhouse gases. Nitrous oxide (N_2O) is the result of denitrification. Again, berry crop production may not be a huge contributor but agriculture overall has a very large foot print in terms of greenhouse gas impact; actually very disproportionate to the share of the gross national product. About 7 to 8% of greenhouse gases are associated with agriculture; most of that is nitrous oxide losses. Nitrous oxide is about 300 times more potent than carbon dioxide. This needs to be reduced as much as possible through prudent and judicious nitrogen management.

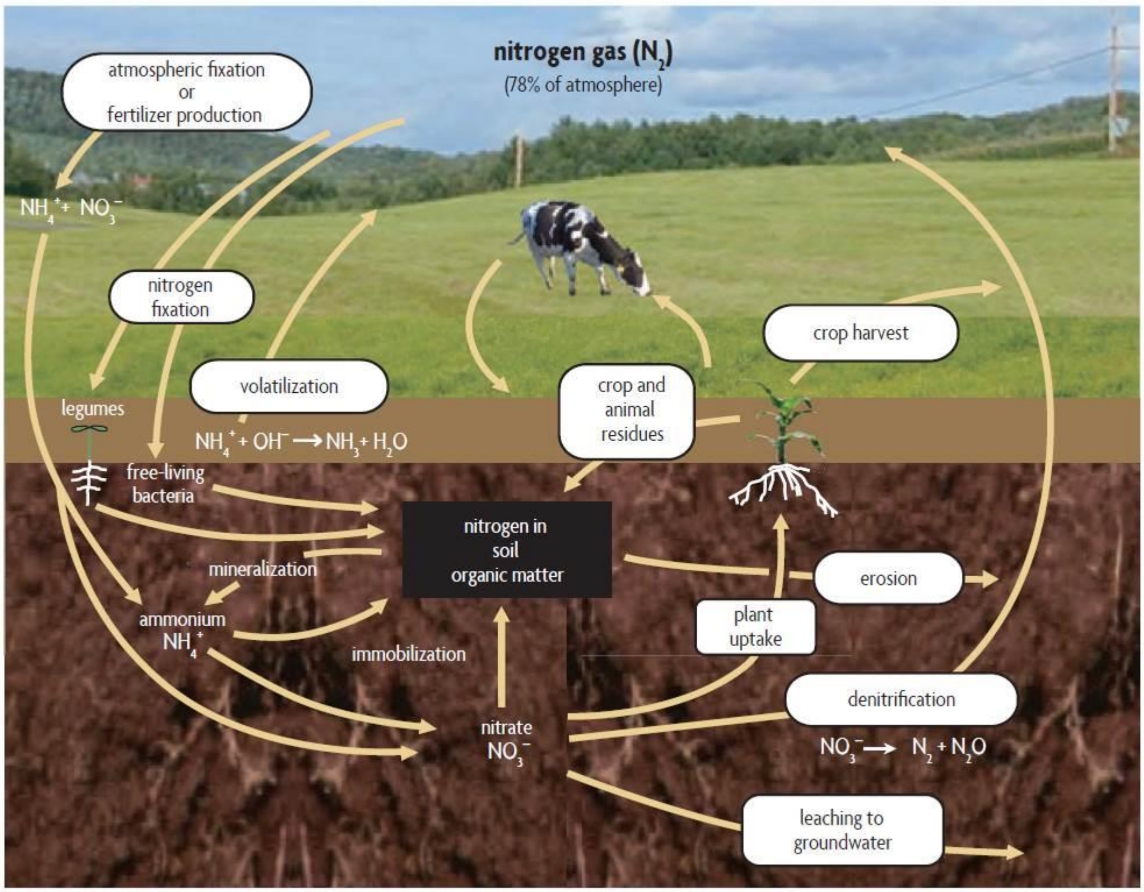
The nitrogen pathway

Returning to our previous pictogram showing pathways for nitrogen and phosphorus losses from soils, we see again crop uptake is the most desirable pathway. Some small amount of loss may occur through erosion but most of the losses will be leaching or denitrification. Leaching losses will occur on a more sandy gravelly soil as nitrate.

Nitrate is negatively charged and the soil is negatively charged as well; causing nitrate to easily percolate down and out of soil. Volatilization and denitrification losses are the nitrogen gas in the atmosphere (N2) which is not at all a concern because 78% of the atmosphere is already di-nitrogen gas. It's primarily the nitrous oxide that's the concern. When a denitrification event occurs, say from a heavy rain event (1 ½" or more), 30 to 40 pounds of nitrogen per acre may easily be lost either through denitrification or leaching.

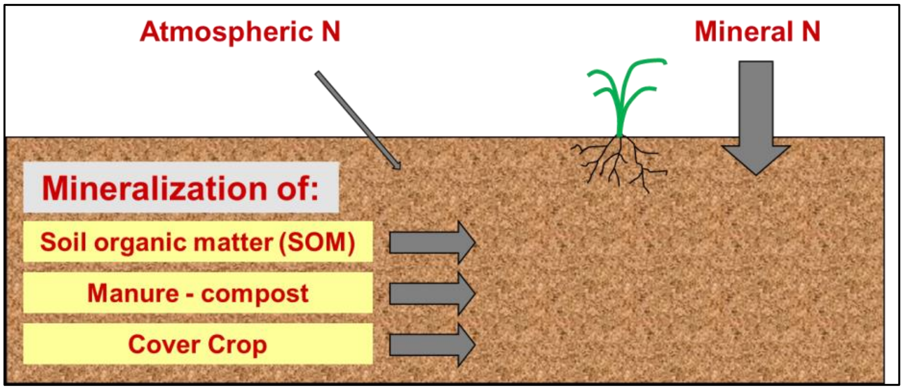
Volatilization of ammonia is the second component in this equation; it is primarily a concern with acidification.

The nitrogen cycle is relatively complex (*below*); we will not go into it in great detail here. Suffice to say a lot of these transformations that occur in the soil are driven in part by all these sources of nitrogen that come from agriculture. When nitrogen moves from one state to another state it may become subject to leaching or denitrification and gaseous losses.



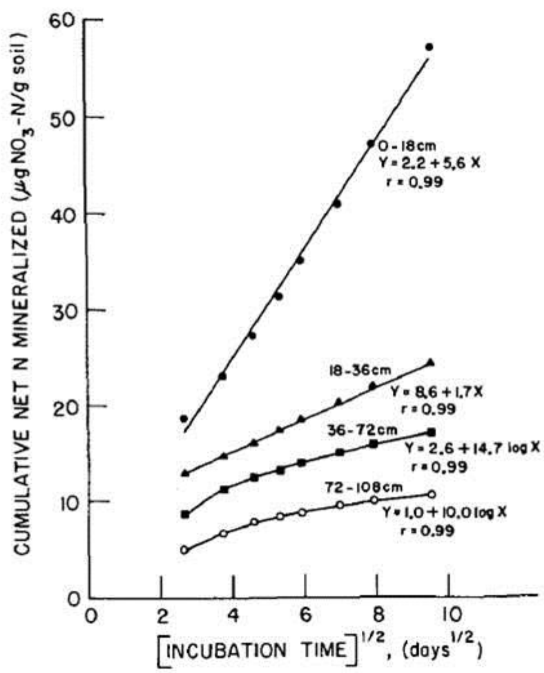
Nitrogen sources

A simplified chart below shows the sources of soil nitrogen. The first source of soil nitrogen is from the atmosphere; typically 6 to 8 pounds per acre; this is free nitrogen, but a relatively small quantity. In most field conditions we get a significant amount of nitrogen from the mineralization (decomposition) of soil organic matter occurring natively in the soil, applied as manure, compost, or residues, or as leguminous cover crops like clover or alfalfa. These get decomposed and the resulting organic nitrogen is mineralized to inorganic nitrogen primarily through biological processes which are in turn affected by temperature. The other source of nitrogen is mineral nitrogen, which is fertilizer, ammonium type fertilizers or nitrate type fertilizers.



There are many sources of variation associated with nitrogen availability, making it a little bit more difficult to manage nitrogen. Different soil types have different sources. If you are looking at Midwestern soils they have a lot of organic matter, are very deep, have good structure. They provide a lot more nitrogen in comparison to a podzol soil in the northeast that is very sandy and has relatively very little organic matter and nitrogen mineralization.

The amount of organic matter in the soil affects nitrogen availability. Soils build up organic matter when they are very well managed; they lose organic matter when they have a history of intensive tillage and/or erosion. How much you add in addition to “native” soil organic matter through application of organic amendments (manure, compost, etc.) , and whether you have cover crops and the types of cover crops you have (leguminous vs. grass covers) affects nitrogen availability. Soil and crop management practices, such as how intensively you till and other things like that affect availability. Presence or absence of drainage and type of drainage has an effect on N availability; if you have poor drainage you may experience significant losses of nitrogen. Temperature plays a role as a lot of the mineralization that occurs (as biological processes) is temperature-mediated. Last but not least precipitation plays a role in nitrogen availability. A soil that is too dry will not mineralize nitrogen; a soil that is too wet will not mineralize nitrogen.



These factors also interact in complex ways, making it difficult to precisely predict how much N needs to be added to soil to adequately feed the crop in question. There are some guidelines, however to help make these decisions once we understand the system a little better

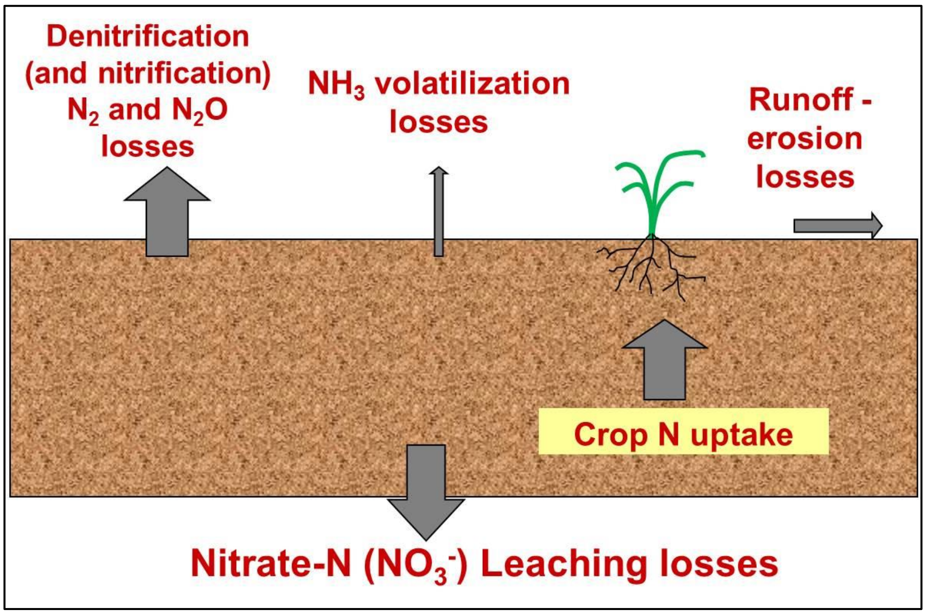
Nitrogen mineralization from soil organic matter

The graph on the right shows nitrogen mineralization as a function of incubation time (*Cassman and Munns, 1980, SSSAJ*). Most of the nitrogen comes from the surface soil, 0 to 18 cm or 0 to 7 inches. . Increasing mineralization occurs up to 10 days. As we go deeper into the soil, less and less nitrogen is mineralized and becomes available. So it’s the surface soil that’s most important, providing the bulk of the nitrogen. This study was a laboratory study. In the field, N release will be affected by weather conditions, soil organic matter content, and soil type.

Pathways for nitrogen losses

There are five pathways for soil nitrogen losses; the preferred pathway of course is uptake by the crop (*Figure 51*). The other 4 pathways potentially lead to problems. Volatilization is one such pathway. If ammonium fertilizers are applied and left on the soil surface they are subject to volatilization. If they are applied by injection or incorporated immediately after application this potential environmental loss may be minimized/eliminated. The same may be true for manures and composts. If they are left on the soil surface and not incorporated, N may be lost through volatilization. Runoff and erosion, in the case of nitrogen, tend not to be primary loss pathways; the exception to this would be when inorganic or organic materials are left on the soil surface and are subsequently subjected to a heavy rain event. The other major losses are denitrification and nitrate leaching.

Figure 51. *Pathways for nitrogen losses*.



Management, soil health, precipitation and temperature are all critical factors in terms of nitrogen losses. As always, when you get a lot of water you get a lot of leaching. Denitrification is affected both by precipitation and by temperature but it's an indirect loss, and a biologically mediated loss. If you have a very cold soil you may have quite a bit of nitrogen in that soil but you won't get much denitrification loss because the soil is cold and the biological activity is low. When we do see a lot of denitrification losses is a little bit further into the growing season when the soil has become warm and you get a lot of rain; losses may be as high as 30 to 50 pounds per acre from a heavy rainfall event. In a way you'd like to be able to account for that.

Going back to our discussion of pore size and environmental losses; small pores reduce leaching losses; large pores reduce denitrification losses. Ideally you have some of both pore sizes. So the best case scenario for reducing nitrogen losses would be a well aggregated soil of medium texture.

Poor internal drainage

If you have barriers deep in the soil and/or water tables at relatively shallow depths, poor soil internal drainage may result. These promote denitrification losses; poor internal drainage can be remediated through installation of subsurface drain lines. Use of raised beds also reduces susceptibility to imperfect drainage. It's a component often forgotten. Poor drainage creates problems not only with nitrogen losses but also with runoff, erosion and phosphorus losses as the soil remains wet and saturated.

Strategies for reducing nitrogen losses

What are the main strategies then for reducing nitrogen losses? First, do not over apply nitrogen by accounting for all sources of N inputs (soil organic matter, manure, compost, fertilizer, etc.).

Ideally, provide N in multiple applications and account for weather factors (precipitation and temperature). On the scientific front progress has been made in this area. We now have for field corn and sweet corn and ADAPT-N tool that allows for prediction of how much nitrogen is needed using model simulations, accounting for all of the weather effects previously discussed here.

For berry producers, even where a tool like that is not available, you can have basic rules of thumb. If you have a very wet spring you probably lost some of that nitrogen through denitrification and leaching, depending on your soil type, and you may to make up for that by applying a little bit of additional nitrogen in your second application. If you have a relatively dry spring you may want to do the opposite; you didn't have any losses and you want to avoid over applying.

Build and maintain soil health (aggregation, OM, etc.), especially on fine textured soils will help to maintain aeration and with water/nutrient retention. So again soil health management is important from not only a production standpoint but also in terms of managing environmental losses.

And finally, as indicated previously, facilitate good drainage.

Soil health and environmental health potential – a case study

Below are two soil health reports for two very similar soils; one soil had a history of manures inputs, the other had a history of no manure inputs. Even those these two soils are inherently very similar, medium textured soils, you can see the aggregate stability without manure (left) was 53% but became 78% with multiple manure inputs. The manure inputs have actually made the soil more desirable by allowing for better aeration, and subsequently reduced potential for denitrification losses.

The available water capacity went from 0.1 to 6 increasing the ability of the soil to retain both water and nutrients, reducing denitrification losses and leaching losses due to the better nutrient and water retention.

Also notice the organic matter content without manure was 2.6; with the manure additional it is built up to over 6%. That has a lot of benefits. The situation is similar with the active carbon (21 vs. 86) and potentially mineralizable nitrogen; the nitrogen value went from 6 to about 23. The soil on the right can provide more nitrogen than the soil on the left. The soil on the right is of higher quality, more desirable, and presumably is of reduced environmental impact.

Without manure inputs				
	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	53	83	
PHYSICAL	Available Water Capacity (m/m)	0.10	12	water retention
PHYSICAL	Surface Hardness (psi)	70	89	
PHYSICAL	Subsurface Hardness (psi)	420	9	Subsurface Pan/Deep Compaction
BIOLOGICAL	Organic Matter (%)	2.6	25	energy storage, C sequestration, water retention
BIOLOGICAL	Active Carbon (ppm) [Permanganate Oxidizable]	460	21	Soil Biological Activity
BIOLOGICAL	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	6.2	1	N Supply Capacity
BIOLOGICAL	Root Health Rating (1-9)	3.5	75	
CHEMICAL	*pH	7.9	0	Toxicity, Nutrient Availability (for crop specific guide, see CNAL report)
CHEMICAL	*Extractable Phosphorus (ppm) [Value <3.5 or >21.5 are downscored]	6.0	100	
CHEMICAL	*Extractable Potassium (ppm)	50	72	
CHEMICAL	*Minor Elements		56	
	OVERALL QUALITY SCORE (OUT OF 100):	45.2		Low

Measured Soil Textural Class:==> silt loam

SAND (%): 40.1 SILT (%): 51.9 CLAY (%): 8.0

Location (GPS): Latitude=> 0 Longitude=> 0

* See Cornell Nutrient Analysis Laboratory report for recommendations

With manure inputs				
	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	78	99	
PHYSICAL	Available Water Capacity (m/m)	0.26	97	
PHYSICAL	Surface Hardness (psi)	239	22	rooting, water transmission
PHYSICAL	Subsurface Hardness (psi)	350	27	Subsurface Pan/Deep Compaction
BIOLOGICAL	Organic Matter (%)	6.1	98	
BIOLOGICAL	Active Carbon (ppm) [Permanganate Oxidizable]	815	86	
BIOLOGICAL	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	22.9	100	
BIOLOGICAL	Root Health Rating (1-9)	5.2	50	
CHEMICAL	*pH	6.7	100	
CHEMICAL	*Extractable Phosphorus (ppm) [Value <3.5 or >21.5 are downscored]	19.5	100	
CHEMICAL	*Extractable Potassium (ppm)	228	100	
CHEMICAL	*Minor Elements		100	
	OVERALL QUALITY SCORE (OUT OF 100):	81.5		High

Measured Soil Textural Class:==> silt loam

SAND (%): 24.3 SILT (%): 69.2 CLAY (%): 6.4

Location (GPS): Latitude=> Longitude=>

* See Cornell Nutrient Analysis Laboratory report for recommendations

Putting it all together

First and foremost, most berry production systems have low environmental impacts from nutrients and sediment. Part of that is inherent with the production practice; the fact you are growing a perennial plant, there's not a lot of tillage going on, there are not a lot of very large amounts of nutrients that get applied.

Site characteristics (soil type, location, etc.) can affect potential losses, for example if you are on a flood plain or have very clayey soils, soils that naturally have higher erosion and runoff potential.

Soil health management has benefits for increased productivity and reduced environmental impacts; a win-win situation.

In addition, we need to be careful what we are putting out there; prudent nutrient management can prevent most of these losses.