Conservation Tillage – Soil Benefits

The primary soil quality impacts are reduced erosion, improved soil organic matter, increased infiltration, and improved soil structure (Figure 8). Leaving all or a portion of the previous crop's residue on the soil surface has three primary roles in reducing sheet and rill erosion:

1. minimizing the splash effect of rainfall,
2. reducing the potential for surface runoff, and
3. increasing infiltration.

Figure 8

Surface residue cover intercepts the falling raindrop and dissipates its erosive energy (Figure 9). Since this energy is dissipated by the residue cover, soil particles are less likely to be dislodged from soil aggregates and as a result, are much less subject to movement by water flowing across the soil surface. Surface residue can also form small dams that slow surface runoff and provide a greater opportunity to infiltrate into the soil. In addition, residue reduces the chances for soil crusting, which can significantly impact infiltration and resulting runoff amounts.

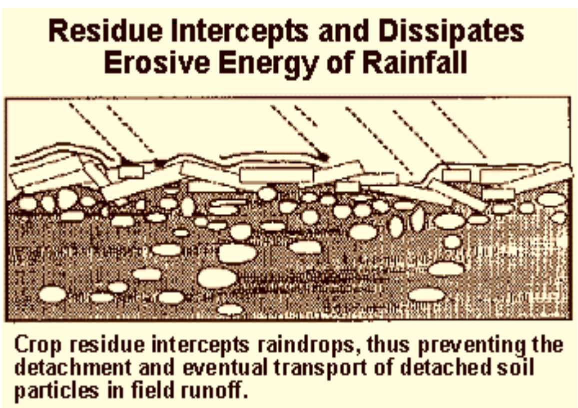

Figure 9

With no-till/strip-till systems, the amount of surface residue cover can approach 80 to 90 percent, potentially reducing sheet and rill erosion by 94 percent or more (Figure 10). After low residue crops, such as soybeans, cotton, or peas, the surface residue cover will be significantly less, perhaps no more than 30 to 40 percent cover. Less surface residue cover will generally be left after planting with ridge-till compared to no-till, because the planting operation removes the residue from the top of the ridge and places it between rows (bare in the rows, but residue cover between the rows).

Effect of Percent Residue Cover on Any Day in Reducing Sheet and Rill Erosion Compared to Conventional, Clean Tillage Without Residue

Residue Cover, % on Any Day	Erosion Reduction, % While Residue is Present
10	30
20	50
30	65
40	75
50	83
60	88
70	91
80	94

Figure 10

With mulch-till, the amount of surface residue can be significantly less than under no-till or ridge-till because full-width tillage is utilized. When high residue crops are used, mulch-till might retain 30 to 50 percent cover, but this is reduced for low residue crops. Another point to remember is that surface residue decomposes over time. Therefore, if you have 60 percent cover after planting with one of the conservation tillage techniques, that amount will decrease throughout the growing season.

Even with flat and well-drained cropland, agricultural fields are generally susceptible to the effects of runoff and erosion. Ephemeral gully erosion is caused by drainage channel depressions in the field where water concentrates and flows over the field (Figure 11). The gullies that are produced can be smoothed with tillage. However, ephemeral gully erosion will occur in the same location year after year if not controlled. As mentioned, less runoff will occur as more crop residue is retained on the soil surface. Since no-till will have the greatest surface cover compared to the other residue management systems, it will have the greatest value in reducing ephemeral gully erosion (Figure 12). For large watersheds or fields with severe gullies, however, a temporary cover or a permanent grassed waterway may be needed to solve the problem.

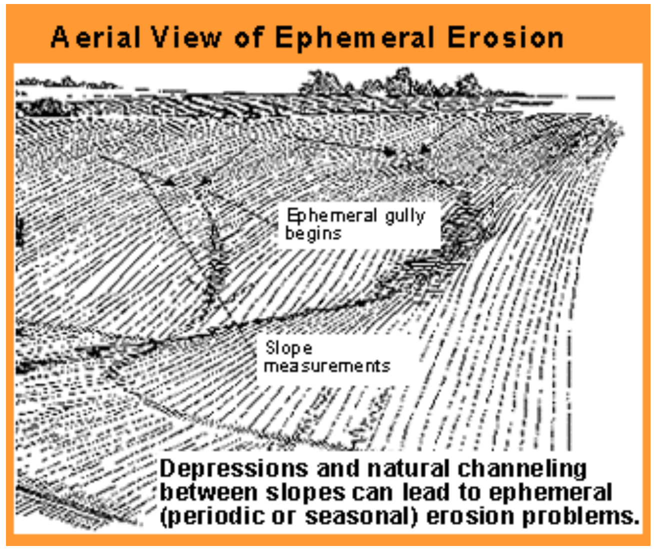

Figure 11

Tillage and residue management practices can have a significant impact in improving soil structure and content of organic matter (Figure 13, next page). The largest increases in soil organic matter result from continuous no-till. Recent research indicates that most of the increase in soil carbon is a result of undisturbed root biomass, not just by leaving crop residue on the surface. Even with continuous no-till, the increase in soil organic matter is a very slow process, sometimes taking many years to replenish.

Figure 12

Some of the soil structure benefits expected to occur from residue management include improved soil aggregate stability, water holding capacity, increased granular structure at the surface, and less surface ponding. The increase in infiltration is primarily a result of improved soil structure, slowed runoff, and leaving the old root and macropore structure undisturbed. Macropores develop from earthworm burrows and decayed root channels. Additionally, high residue management systems can significantly increase plant available water. This is an extremely important benefit, especially in areas where crop moisture stress is common or irrigation supplies are limited.

Conservation Tillage – Water and Air Quality Benefits

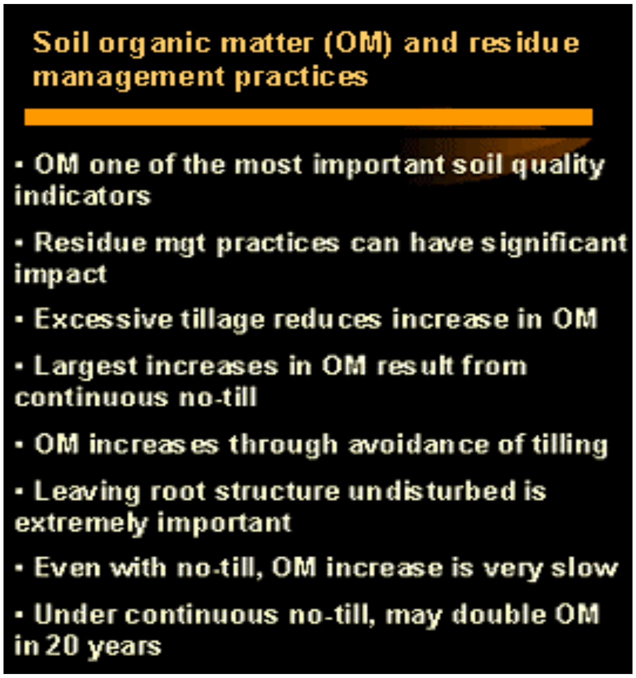

Figure 13

Sediment is the number one non-point source pollutant in the United States (Figure 14). Traditional tillage practices completely expose the soil surface, potentially leading to increased rates of erosion and runoff containing significant amounts of sediment. Nutrients, such as phosphorus and nitrogen, and pesticides and herbicides can also be transported off a farmer's field by dissolving in runoff or attaching to soil particles that are eroded and carried away with runoff. But even clean sediment that builds up excessively in streams can cause physical problems such as degraded stream habitats and fewer fish, loss of pool depth, increased expense of water filtration, and suffocation of eggs and young in spawning beds.

Because tillage and residue management practices significantly reduce soil erosion and increase infiltration, the amount of sediment leaving the field and reaching surface waters is greatly reduced. Conservation tillage practices therefore limit water quality problems and the potential threats to fish, benthic organisms, and aquatic plants.

Traditional tillage practices also expose the soil surface to wind erosion. Small particulate matter, or dust from these tillage operations can be blown off the field. These very fine particles have been identified as a potential health hazard. No-till/strip-till, ridge-till, and mulch-till practices may provide sufficient residue cover to reduce wind erosion and dust production during these operations. Under low residue producing crops, erosion by wind can occur and could present serious problems in all three residue management practices. Cover crops, where practical, can be utilized to increase surface residue cover. Other supporting practices such as Cross Wind Trap Strips, Herbaceous Wind Barriers, and Field Windbreaks can be used to further reduce the wind erosion hazard.

Figure 14

CORE 4 4 MORE

Conservation Tillage – Economic Considerations

The overall economics of different tillage/production systems varies between regions, crops, individual farms and even between fields. Although savings in input costs may be significant for some systems, yields play a major factor in overall profitability. The two biggest economic factors, which may cause producers to consider conservation tillage systems such as no-till, are **labor and equipment savings**. When conservation tillage systems are applied there are fewer trips made compared to conventional or intensive tillage systems, resulting in fuel savings, less equipment, less equipment repairs, and less labor. As tillage is decreased, herbicides are more important for weed control. However, other than the cost of burndown herbicide, the overall cost for weed control is generally not any different between tillage systems. The Economic Research Service reports, "factors other than tillage that affect pest populations may have a greater impact on pesticide use than type of tillage."

	No-till	Conventional
Direct Costs		
Seed	$26	$25
Fertilizer	$72	$67
Pesticide	$32	$28
Field Operations	$56	$74
Total direct costs	$186	$194
Indirect Costs		
Land	$120	$120
Hauling	$13	$13
Drying	$23	$21
Interest	$13	$13
Total indirect costs	$169	$167
Total Costs	$355	$361
Total Yield	$160	$160
Price	2.45/bu	2.45/bu
Total Income	$392	$392
Profit	$37	$31
Although itemized costs may differ slightly, this budget indicates that overall costs between no-till and conventional tillage systems can be very similar.		

Figure 15: Sample crop budget for corn per acre

Reduced labor cost is a major factor in adopting no-till in some areas. As farms increase in size producers are looking for ways to farm these acres but without adding additional help or equipment. Conservation tillage facilitates expansion on larger acreages or allows operators to use the time savings for livestock operations, grain marketing, or off-farm employment. Machinery savings may also be substantial in a no-till system. If a producer is able to convert to a complete no-till system, then a long list of primary and secondary machinery is not needed. In addition, less maintenance is needed since the machinery is not being operated as many hours each year. Although the cost of no-till equipment is considerably less than comparable equipment required for conventional tillage, it makes further economical sense if the existing line of equipment is old and needs replacement.

Generally speaking no-till systems offer a slight to fairly significant reduction in input costs. If proper management of conservation tillage is used, yields are likely to be maintained, costs will decrease, an overall improvement in the efficiency of a farm operation will result and thus enhance profitability (Figure 15). In areas where moisture retention is improved, yield increases can be expected along with improved profits.

Core 4 Principle #2: Crop Nutrient Management

Nutrients are essential to all plant and animal life. Agricultural crops generally obtain their nutrients through roots or leaves, from the soil, water, and atmosphere. Sixteen elements have been identified as being essential to plant growth:

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Sulfur (S)
- Calcium (Ca)
- Magnesium (Mg)
- Iron (Fe)
- Copper (Cu)
- Zinc (Zn)
- Manganese (Mn)
- Molybdenum (Mo)
- Chlorine (Cl)
- Boron (B)

Carbon, hydrogen, and oxygen are not mineral nutrients, but are the products of photosynthesis. N, P, K, S, Ca, and Mg, are considered macronutrients, because they are needed in relatively large amounts and must often be added to the soil for optimum crop production. The others - Fe, Cu, Zn, Mn, Mo, Cl, and B, are considered micronutrients, because they are needed only in minute amounts and are usually (though not always) present in the soil in ample quantities for crop production (Figure 16).

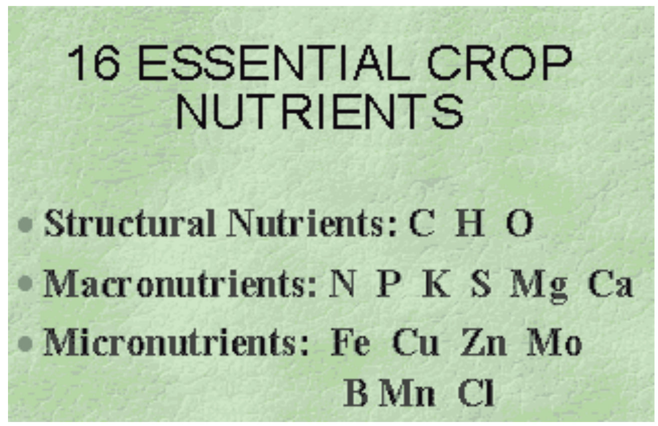

Figure 16

The practice of crop nutrient management serves four major functions:

1. It supplies essential nutrients to soils and plants so that adequate food, forage and fiber can be produced.
2. It provides for efficient and effective use of scarce nutrient resources so that these resources are not wasted.
3. It minimizes environmental degradation caused by excessive nutrients in the environment, especially in waterbodies that receive runoff from fertilized fields and other agricultural lands.
4. It helps maintain or improve the physical, chemical, and biological condition of the soil.

Proper nutrient management economizes the natural process of nutrient cycling to optimize crop growth and minimize environmental impacts.

Crop Nutrient Management – Nutrient Properties

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All plant nutrients are cycled through the environment (Figure 17). Three of the nutrients most often limiting to crops - nitrogen (N), phosphorus (P), and potassium (K) - have unique cycles dictated by chemical and biological transformations, movement in soils, and transport by runoff and erosion (Figures 18–20). Nutrients in the soil are absorbed by plants and incorporated in plant phytomass. When these plants die, the nutrients in their phytomass are decomposed by soil organisms, especially microorganisms, and returned to the soil where the cycle begins again.

Nutrient cycles are "leaky", however. If nutrients are present in the soil in greater quantities than they are needed or at times when they cannot be used by crops or soil microbes, they may be lost to the environment through runoff, erosion, leaching, or volatilization. Nutrient availability to crops also depends on the chemical form in which nutrients are present. Nutrients present in an unavailable form will not be taken up by plants even though they may be needed, and may be lost from the cycle. Nitrogen in particular undergoes a number of transformations as it is cycled. These transformations occur under different environmental conditions and understanding when they are likely to occur can help improve nutrient management planning.

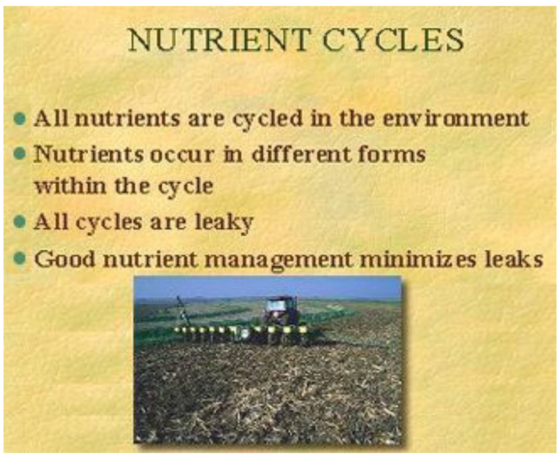

Figure 17

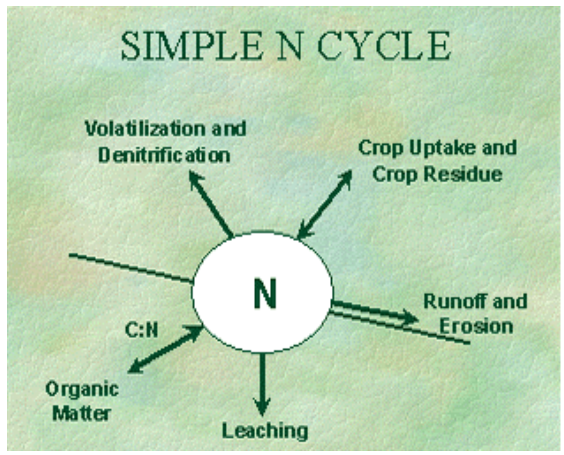

Figure 18

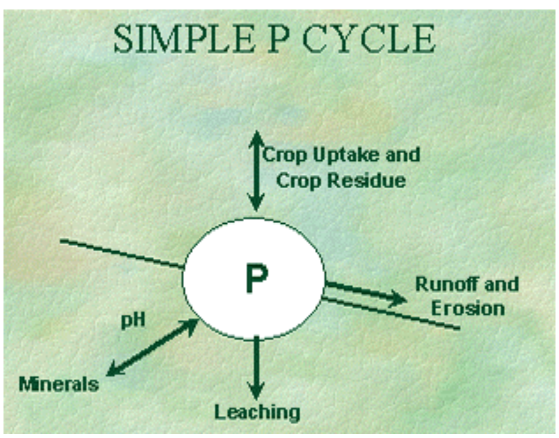

Figure 19

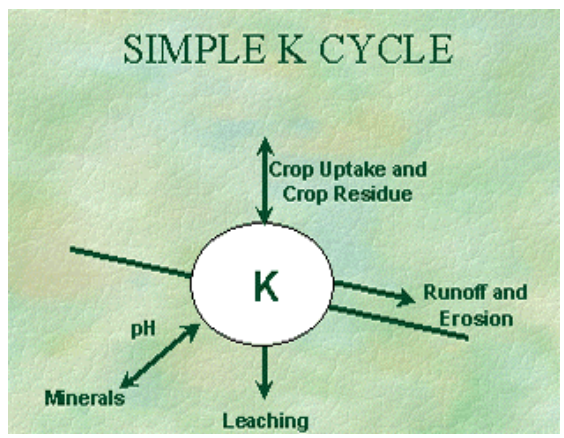

Figure 20

Nitrogen is usually the most limiting nutrient in crop production systems and is added to the soil environment in the greatest amount of any of the plant nutrients. Increases in nitrogen content of the soil and plant uptake generally lead to higher nitrogen and protein content of the plant as well as yield. Nitrogen in the soil system can present an environmental risk to the atmosphere, ground water, and surface water. Significant amounts of surface applied ammonium (NH_4^+) can be lost to the atmosphere as ammonia gas (NH_3) through volatilization. These additions of nitrogen to the atmosphere can contribute to the greenhouse effect and acid rain. Excess movement of nitrogen, primarily from runoff and erosion or leaching, into ground water and surface water can lead to degradation of water quality. Conservation buffer practices may help reduce runoff or leaching losses by filtering out nutrient-rich sediments, enhancing infiltration (which can reduce soluble losses from runoff), and taking up nitrogen and other nutrients before they reach water bodies.

Phosphorus is also an essential nutrient for plant growth and occurs in the soil as inorganic orthophosphate and organic compounds. Although the total amount of phosphorus in the soil is large, the quantity of plant available phosphorus in the soil solution is very small, ranging from 0.25 to 3.00 pounds per acre. Phosphorus applied to the land surface either as manure or commercial fertilizer is primarily lost through the process of surface runoff and erosion. Approximately 80 to 90 percent of the phosphorus load is carried in the sediment. The remaining 10 to 20 percent is carried in runoff. Generally, phosphorus lost in runoff amounts to less than 5 percent of that applied to agricultural land. From a crop production standpoint, this amount is considered to be insignificant. From a water quality standpoint, this small amount can lead to significant reduction in surface water quality.

Potassium (K^+) is utilized in relatively large quantities by plants. The nutrient plays an important role in plant hardiness and disease tolerance. If a soil is high in potassium, forage crops will take up potassium at the expense of magnesium, causing an imbalance in the plant. Cattle grazing this forage will not get enough magnesium, which can lead to the ailment grass tetany. Potassium is also showing up as an imbalance in cattle rations when forages grown on high soil K fields are fed to dairy cattle. Again the imbalance of K to other nutrients, namely calcium and magnesium, is the problem. There are no known deleterious effects of K in fresh or saline waters except to increase the salt content and electric conductivity.

Excess Nutrients and Impact on the Environment

Nutrients are essential for life, but excessive levels can become a burden on the environment and often create an imbalance in the ecosystem (Figure 21). These impacts can vary depending on properties of the nutrient, the concentration, and the characteristics of the nutrient cycle.

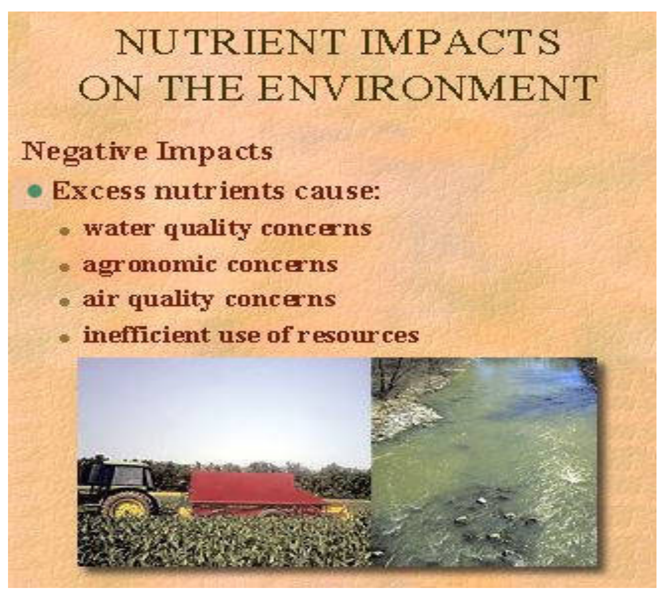

Figure 21

Some examples of nutrients out of balance with the environment are:

- Excess growth of aquatic plants, including algae and submerged weeds can impair the desired uses of the water body (Figure 22). In general, phosphorus tends to be the cause of eutrophication in fresh waters, while nitrogen is primarily the cause in estuarine or marine waters.
- Excess nitrate-nitrogen and nitrite-nitrogen can be a health risk to humans and animals. Water concentrations of nitrate nitrogen greater than 10 mg/L are considered to be unsafe for human consumption, in particular for small babies.
- Ammonia (NH3) produced in animal manures and other organic nutrient sources can become toxic to aquatic life. Levels greater than 0.02 mg/L are considered toxic to fresh water aquatic life, including fish (Figure 23).
- Nutrition of forages becomes out of balance when levels of potassium are high. Such nutrient imbalances cause poor livestock health and can even lead to serious illness.
- Excess nutrients can lead to air quality problems such as ammonia volatilization, production of greenhouse gases, and offensive odors.

Nutrient enrichment can lead to excess algae growth.

Figure 22

NH3 is toxic to fish.

Figure 23

Crop Nutrient Management – Assessment Tools

The objective of nutrient management is to supply adequate chemical elements to the soil and plants without creating an imbalance in the ecosystem. All the things that affect the environment (climate, soils, air, water, human activities) will affect the fate and transport of nutrients. Precipitation events and temperature have a large influence on nutrient transformation, transport, and even additions to the soil-plant-air-water-animal system, yet they are difficult to manage.

Nutrient sources, such as the application of fertilizer, irrigation water, and organic materials, are the easiest to control. Monitoring nutrients in the environment through soil, water, air, plant, and animal testing is the most direct way of knowing what levels exist. Adjusting the inputs based on the current levels of nutrients available and amount required for crop production is the best way to maintain crop production and avoid excess accumulations.

It is imperative to retain the nutrients where they can be most efficiently used by the plant. This is generally in the soil where roots are or will soon grow to. Environmental influences, like rainfall, wind, and gravity tend to move nutrients away from the root zone. The forces of wind and water erosion should be managed to minimize the movement of nutrient-enriched soil particles from leaving the field. Improving soil surface structure and promoting greater infiltration will reduce runoff and the loss of soluble nutrient forms.

Management of irrigation water and continuation of plant growth during the high rainfall/low evapotranspiration periods will modify the amount of soil moisture capable of carrying nutrients below the root zone. Soil type affects leaching potential, so management of nutrients by soil type is also important. In summary, to protect the environment from excess nutrients, both the source of nutrients and the transport must be properly managed.

A wide variety of assessment tools are available to nutrient managers (Figure 24). Assessment tools generally fall into one of two categories:

1. Tools to assess the agronomic needs of a crop
2. Tools that assess environmental risk associated with nutrient applications

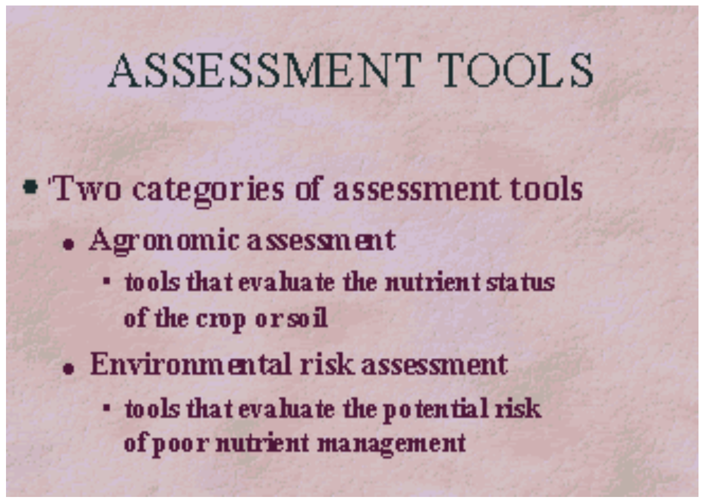

Figure 24

Properly using one or both of these types of tools can significantly improve nutrient management decisions.

- **Agronomic needs assessment tools** provide information on the status of crops, soils, and soil amendments (Figure 25). They help the nutrient management planner develop a more accurate nutrient budget to determine the amount and type of nutrients actually required by the soil-plant system.

  Agronomic needs assessment tools include the following (Sample techniques for these tests should follow Extension Service guidelines):

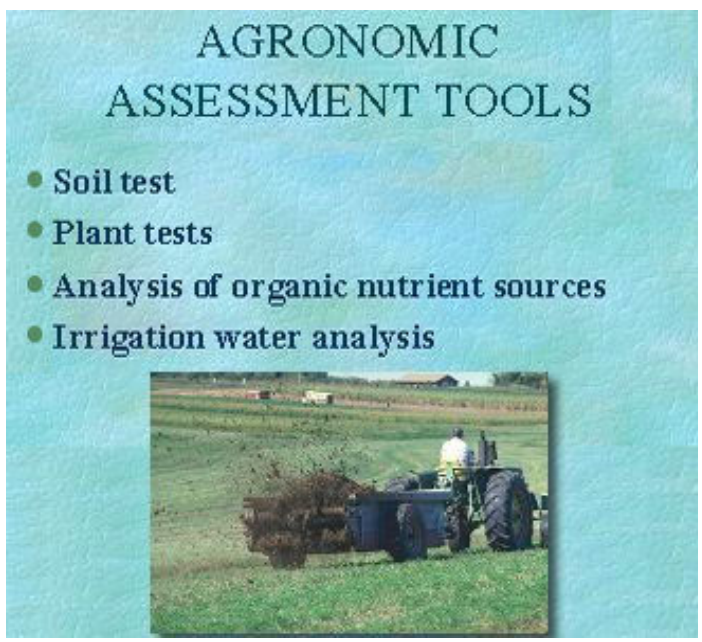

Figure 25

Traditional soil tests - these include tests for pH, nitrogen, phosphorus, potassium, soil organic matter, and electrical conductivity. Soil tests give the nutrient management planner a sense of the nutrient supply in the soil. If soil test levels of individual nutrients are HIGH, there may be no need to apply additional fertilizers. If they are LOW or MEDIUM

fertilization will probably be advisable. Traditional soil tests provide an important baseline of information and should be performed regularly every 3 to 5 years, or more often if conditions change.

Nitrate test - In certain parts of the country, the pre-plant nitrate test and the pre side-dress nitrate test are used to determine whether or not additional nitrogen is necessary. The deep nitrate test is another tool performed to determine how much nitrogen has already leached below the crop rooting-zone.

Traditional plant tests - A variety of plant tests are available and being developed to provide information on the nutrient status of the crop. The chlorophyll meter, for example, has been used to quickly determine nitrogen status of the crop without destroying any plant tissue.

Organic material analysis - Organic materials, such as manure, municipal wastewater sludge, or other organic products, are often applied to cropland as nutrient sources. Unlike commercial fertilizers, the nutrient content of these amendments is variable and should be tested.

Irrigation water test - Because the salt status and pH of irrigation water can often impact crop uptake of both water and nutrients, water that is applied to cropland may be tested for electrical conductivity and pH. Surface irrigation water may also be tested for nitrate, since a high level of nitrate in the water may indicate a reduced need for fertilization.

- **Environmental risk assessment tools** provide information on the potential environmental risk associated with nutrient applications. Environmental risk assessment tools may be used to identify sensitive areas in which careful nutrient management is critical to protect a water resource or where nutrient applications should be critically limited. Risk assessment tools may involve simple analyses or elaborate models (Figure 26).

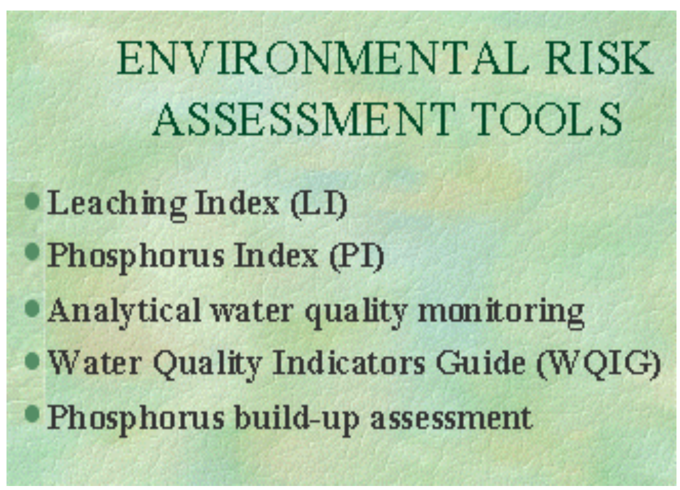

Figure 26

Components of a Nutrient Management Plan

The management of nutrients becomes a part of the overall conservation plan. There are a few basic elements that need to be a part of the nutrient management component of a complete plan (Figure 27). These elements guide the producer in making decisions on the placement, rate, timing, form, and method of nutrient application. These elements also help producers become fully aware of the steps that need to be taken to successfully manage their nutrients and protect the natural resources of the community. The plan must be implemented to meet these goals.

Figure 27

The effective implementation of the plan requires frequent review of the plan, periodic monitoring of progress, and continual maintenance. Planning sets the framework for results that are accomplished by on-the-land implementation. The nine elements listed in Figure 27 are not intended to be all-inclusive, but are the minimum requirements for the nutrient management plan component of a conservation plan (a further explanation of each component is listed below).

Sometimes there are unforseen circumstances that will require a change in the nutrient management components. The climate, producer’s health, or the economics of the livestock and commodity markets all can disrupt the planned components of nutrient management and require some modifications. For example, wet weather and saturated soil conditions may prevent application of animal manure prior to planting of the planned crop. Alternative nutrient sources must be found as well as additional land area to apply the manure at a later time. Any changes to the nutrient management plan components should be made in a timely manner and based on the overall plan objectives.

1. ***Site maps, including soil map*** - These maps are generally part of the over-all conservation plan. However, additional site information may be needed for the fields where nutrients will be applied. This information may include proximity to sensitive resource areas, areas with some type of restriction on nutrient applications, and soil interpretations for nutrient application.