U.S. Environmental Protection Agency

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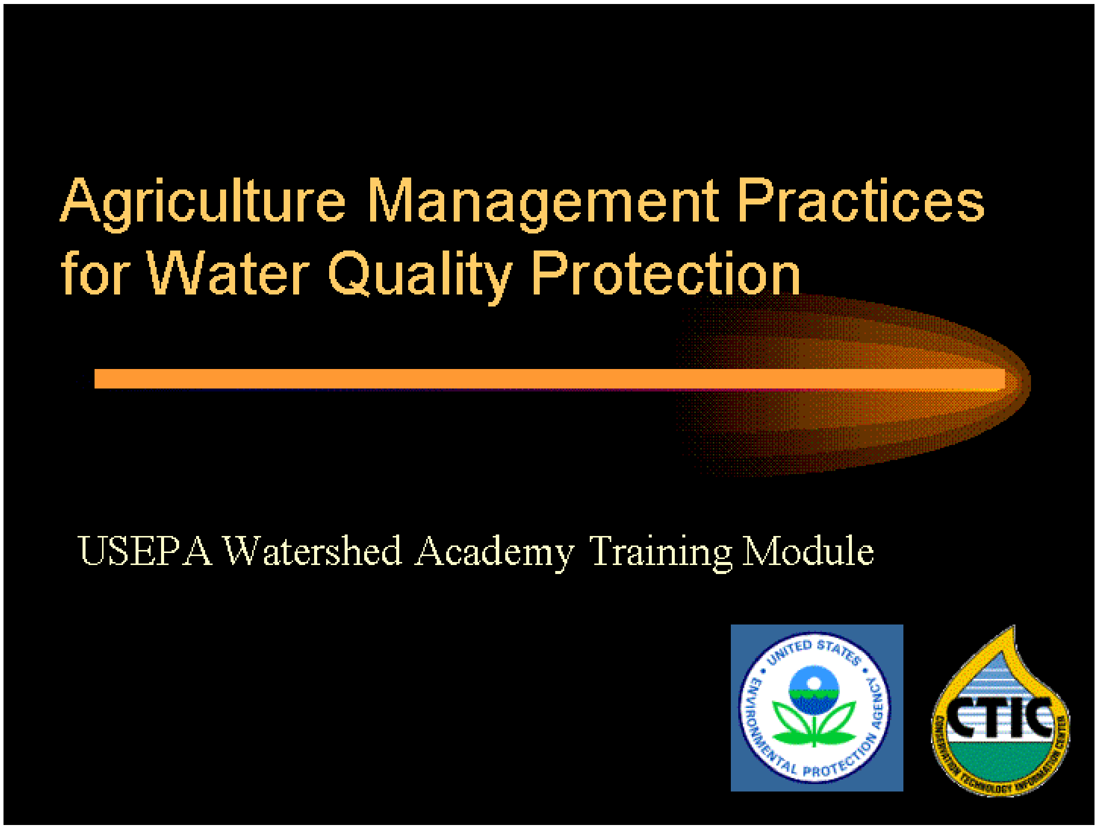

Agriculture Management Practices for Water Quality Protection

USEPA Watershed Academy Training Module

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Introduction

Welcome to the ***Agricultural Management Practices for Water Quality Protection*** module. This training unit introduces eight basic types of agricultural practices that are suitable for reducing or minimizing water quality impacts, as part of an overall watershed approach. These practices are often called Best Management Practices, or BMPs. We based this module on two primary information sources:

- ***CORE 4***, an outreach program for the agriculture community, developed by the Conservation Technology Information Center (CTIC) (http://www.ctic.purdue.edu/CTIC/CTIC.html) for the USDA Natural Resources Conservation Service.
- EPA's ***National Management Measures to Control Nonpoint Source Pollution***, which is non-regulatory, national guidance for agriculture that is issued to help farmers reduce non-point source pollution.

This module has two parts. Part 1 summarizes the use and value of the CORE 4 conservation practices using training materials developed by CTIC. The CORE 4 program promotes reducing non-point sources of pollution from croplands through integrated use of the following four complementary practices (Figure 1):

The four agricultural management practices of CORE 4 ….

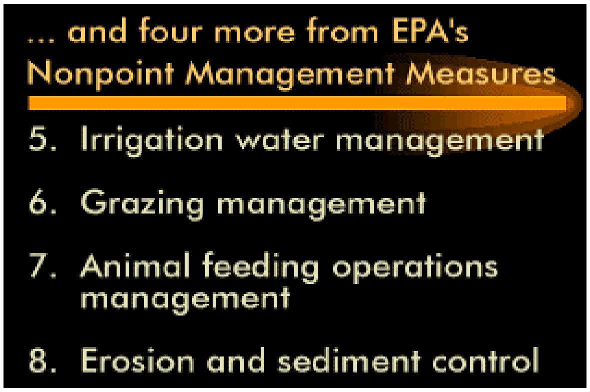
1. Conservation tillage
2. Crop nutrient management
3. Pest management
4. Conservation buffers

Figure 1

1. ***Conservation Tillage*** - leaving crop residue (plant materials from past harvests) on the soil surface reduces runoff and soil erosion, conserves soil moisture, helps keep nutrients and pesticides on the field, and improves soil, water, and air quality;
2. ***Crop Nutrient Management*** - fully managing and accounting for all nutrient inputs helps ensure nutrients are available to meet crop needs while reducing nutrient movements off fields. It also helps prevent excessive buildup in soils and helps protect air quality;
3. ***Pest Management*** - varied methods for keeping insects, weeds, disease, and other pests below economically harmful levels while protecting soil, water, and air quality;
4. ***Conservation Buffers*** - from simple grassed waterways to riparian areas, buffers provide an additional barrier of protection by capturing potential pollutants that might otherwise move into surface waters.

Part 2 details four additional agricultural BMPs that can be considered for increased protection and benefits. These supplemental agricultural BMPs are aimed at benefiting production while protecting the environment, and are highlighted in the EPA's guidance manual *National Management Measures to Control Nonpoint Source Pollution from Agriculture* (Figure 2, next page):

5. ***Irrigation Water Management* -** reducing nonpoint source pollution of ground and surface waters caused by irrigation systems;
6. ***Grazing Management* –** minimizing the water quality impacts of grazing and browsing activities on pasture and range lands;
7. ***Animal Feeding Operations (AFOs) Management* -** minimizing impacts of animal feeding operations and waste discharges through runoff controls, waste storage, waste utilization, and nutrient management;
8. ***Erosion and Sediment Control* -** conserving soil and reducing the mass of sediment reaching a water body, protecting both agricultural land and water quality and habitat.



... and four more from EPA's
Nonpoint Management Measures

5. Irrigation water management
6. Grazing management
7. Animal feeding operations management
8. Erosion and sediment control

Figure 2

PART ONE: CORE 4 PRINCIPLES

CORE 4 ●○○○ 4 MORE ○○○○

Core 4 Principle #1: Conservation Tillage

Conservation tillage practices are used in crop production to reduce negative effects on soil, water, and air quality (Figure 3). The three primary conservation tillage practices are designed to limit tilling requirements while maintaining a crop residue on the soil surface.

1. ***No-till/Strip-till*** are similar systems that can be described as managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year round, while planting crops in narrow slots or tilled strips in previously undisturbed soil. No-till is defined by NRCS as leaving all of the residue on the soil surface and disturbing no more than 10 percent of the soil surface while planting (Figure 4, next page).

Minimizing tillage and maintaining a crop residue on the soil surface can greatly reduce erosion impacts

Figure 3

2. ***Mulch-till*** systems manage crop residue on the soil surface year round, while growing crops where the entire soil surface is tilled prior to or during the planting operation. Residue is partially incorporated using chisels, sweeps, field cultivators, or similar farming implements. Mulch-till is defined as leaving 30 percent crop residue cover after planting (Figure 5).
3. ***Ridge-till*** systems manage crop residue on the soil surface year round, while growing crops on pre-formed ridges alternated with furrows protected by crop residue (Figure 6).

Crops grown using conservation tillage techniques preserve plant residue on the soil surface and minimize soil disturbance with specialized cultivation equipment.

Figure 4

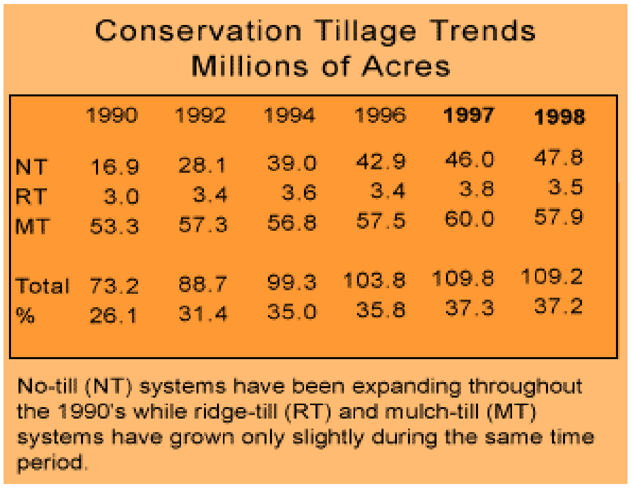
Although each of the residue management practices can have favorable impacts on soil, water, and air quality, they can vary in the degree of this impact. The benefits are gradually being accepted by the farming community, resulting in increased implementation of conservation tillage in the United States (Figure 7).

Mulch-till systems partially incorporate crop residue in the soil while maintaining a portion as cover after planting.

Figure 5

In a ridge-till system, since next year's crop is planted on this year's ridge, care must be taken to protect the shape and height of the ridge during the harvesting operation.

Figure 6



Conservation Tillage Trends
Millions of Acres

	1990	1992	1994	1996	**1997**	**1998**
NT	16.9	28.1	39.0	42.9	46.0	47.8
RT	3.0	3.4	3.6	3.4	3.8	3.5
MT	53.3	57.3	56.8	57.5	60.0	57.9
Total	73.2	88.7	99.3	103.8	109.8	109.2
%	26.1	31.4	35.0	35.8	37.3	37.2

No-till (NT) systems have been expanding throughout the 1990's while ridge-till (RT) and mulch-till (MT) systems have grown only slightly during the same time period.

Figure 7

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.

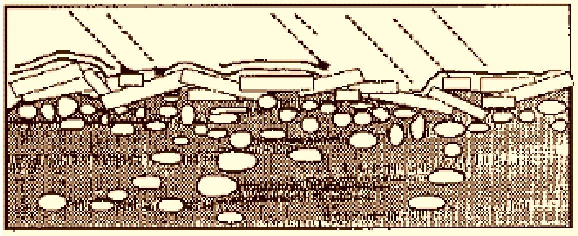
Surface residue cover intercepts the falling raindrop and dissipates its erosive energy (Figure 9). Since this energy is dissipated by the residue cover, soil particles are less likely to be dislodged from soil aggregates and as a result, are much less subject to movement by water flowing across the 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.

Expected changes in soil structure with residue management systems

- Improved soil aggregate stability
- Improved water holding capacity
- Less surface ponding of rainfall
- Increased granular structure at surface

Figure 8

Residue Intercepts and Dissipates Erosive Energy of Rainfall

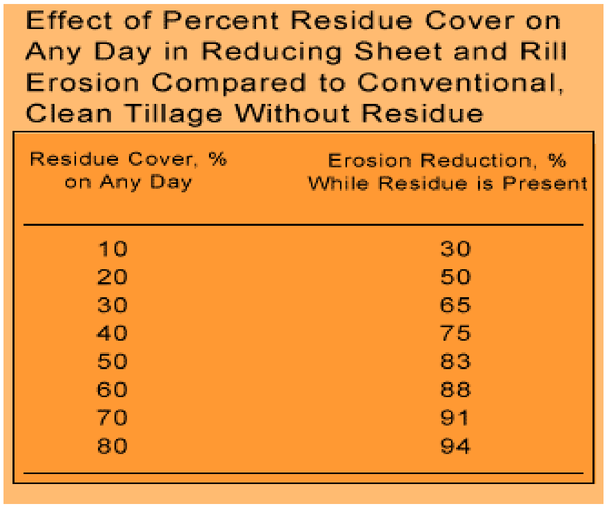


Crop residue intercepts raindrops, thus preventing the detachment and eventual transport of detached soil particles in field runoff.

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).

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

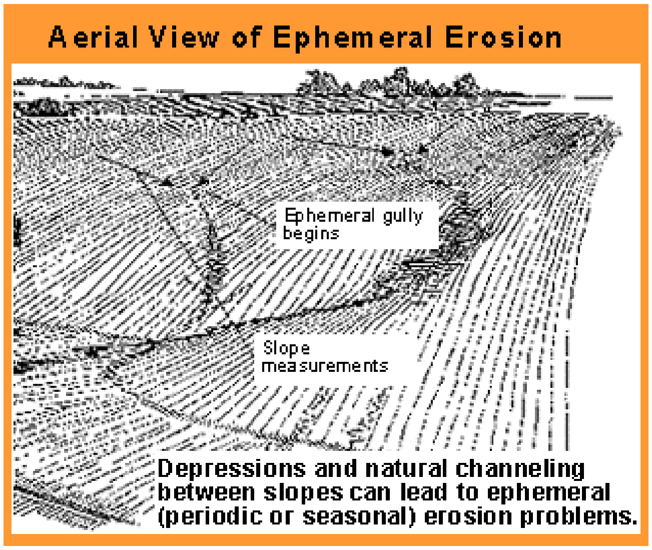


Effect of Percent Residue Cover on Any Day in Reducing Sheet and Rill Erosion Compared to Conventional, Clean Tillage Without Residue

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

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.


Aerial View of Ephemeral Erosion

Depressions and natural channeling between slopes can lead to ephemeral (periodic or seasonal) erosion problems.

Figure 11

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.

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.

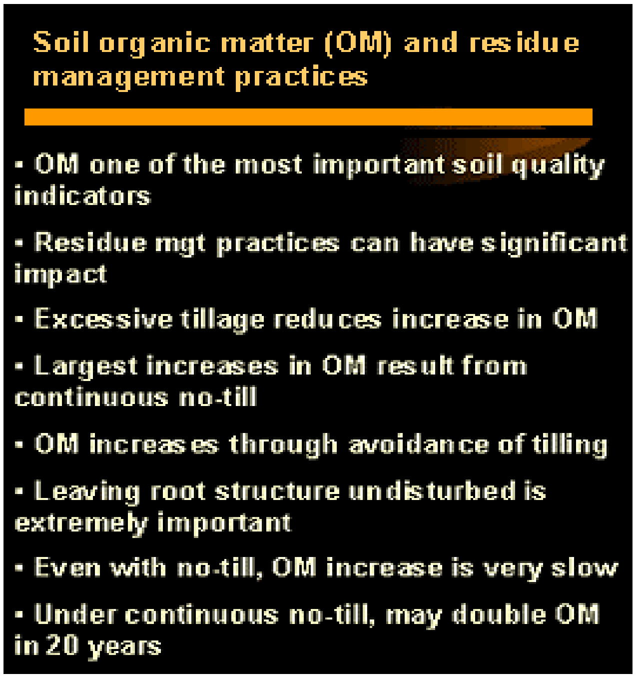

Effect of crop residue on ephemeral erosion:

- Less runoff as surface residue increases
- No-till leaves the most surface residue
- No-till has greatest value in reducing ephemeral erosion
- Effectiveness depends on soil permeability and watershed size

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



Soil organic matter (OM) and residue management practices

- OM one of the most important soil quality indicators
- Residue mgt practices can have significant impact
- Excessive tillage reduces increase in OM
- Largest increases in OM result from continuous no-till
- OM increases through avoidance of tilling
- Leaving root structure undisturbed is extremely important
- Even with no-till, OM increase is very slow
- Under continuous no-till, may double OM in 20 years

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.

Water Quality - Sediment

- Sediment is #1 pollutant
- Creates physical problems
- Potential hazard to fish and wildlife

Figure 14

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.

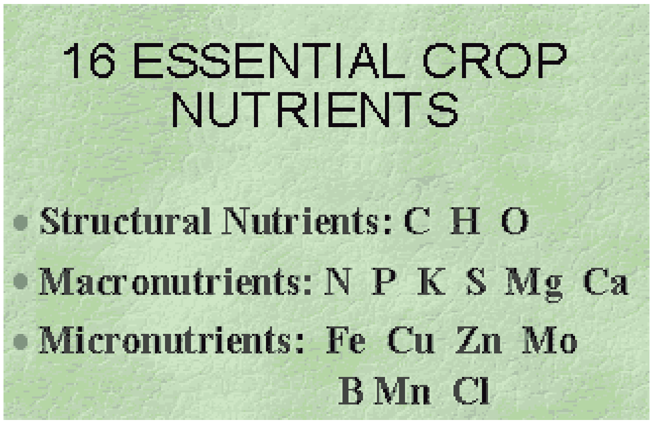
Generally speaking no-till systems offer a slight to fairly significant reduction in input costs. If proper management of conservation tillage is used, yields are likely to be maintained, costs will decrease, an overall improvement in the efficiency of a farm operation will result and thus enhance profitability (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).



16 ESSENTIAL CROP NUTRIENTS

- Structural Nutrients: C H O
- Macronutrients: N P K S Mg Ca
- Micronutrients: Fe Cu Zn Mo B Mn Cl

Figure 16

The practice of crop nutrient management serves four major functions:

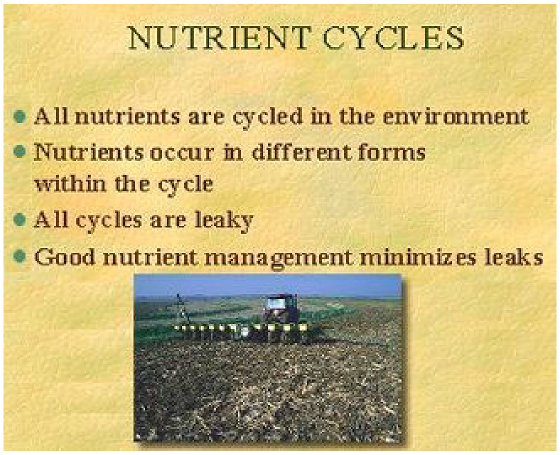
1. It supplies essential nutrients to soils and plants so that adequate food, forage and fiber can be produced.
2. It provides for efficient and effective use of scarce nutrient resources so that these resources are not wasted.
3. It minimizes environmental degradation caused by excessive nutrients in 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

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.


NUTRIENT CYCLES

- All nutrients are cycled in the environment
- Nutrients occur in different forms within the cycle
- All cycles are leaky
- Good nutrient management minimizes leaks

Figure 17

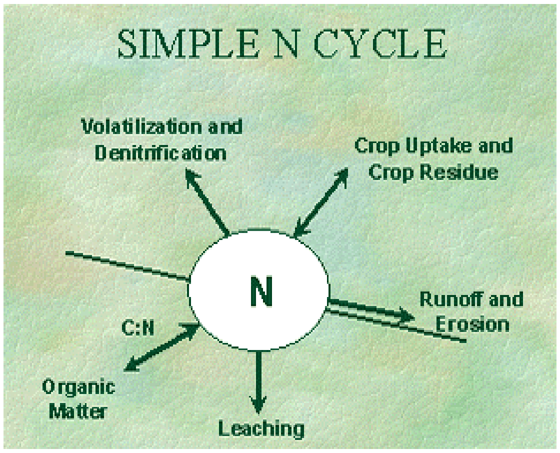


Figure 18

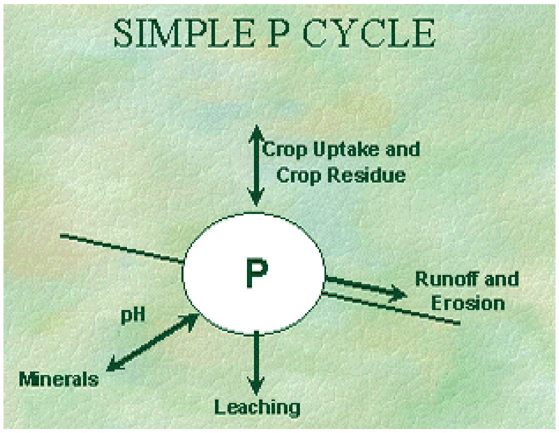


Figure 19

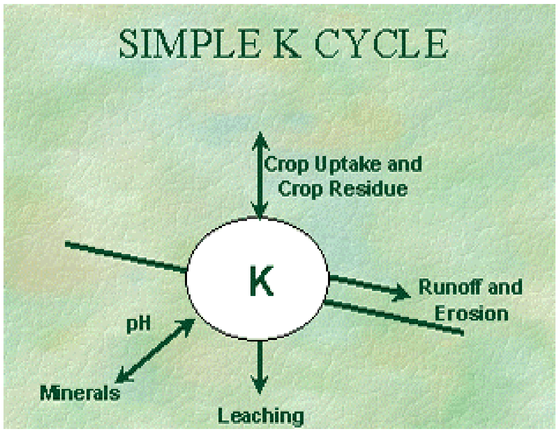


Figure 20

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 ($NH4+$) can be lost to the atmosphere as ammonia gas ($NH3$) 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.

NUTRIENT IMPACTS
ON THE ENVIRONMENT

Negative Impacts

- Excess nutrients cause:
  - water quality concerns
  - agronomic concerns
  - air quality concerns
  - inefficient use of resources

Figure 21

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


Nutrient enrichment can lead to excess algae growth.

Figure 22


NH3 is toxic to fish.

Figure 23

- 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 (NH_3) 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.

CORE 4 ○●○○ 4 MORE ○○○○

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.

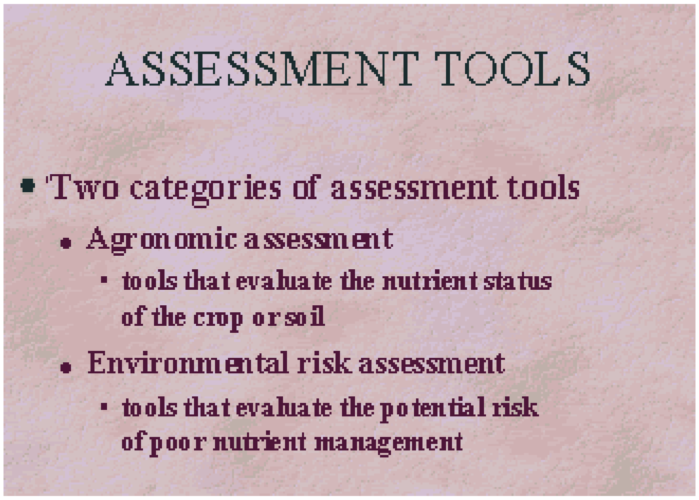
It is imperative to retain the nutrients where they can be most efficiently used by the plant. This is generally in the soil where roots are or will soon grow to. Environmental influences, like rainfall, wind, and gravity tend to move nutrients away from the root zone. The forces of wind and water erosion 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

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



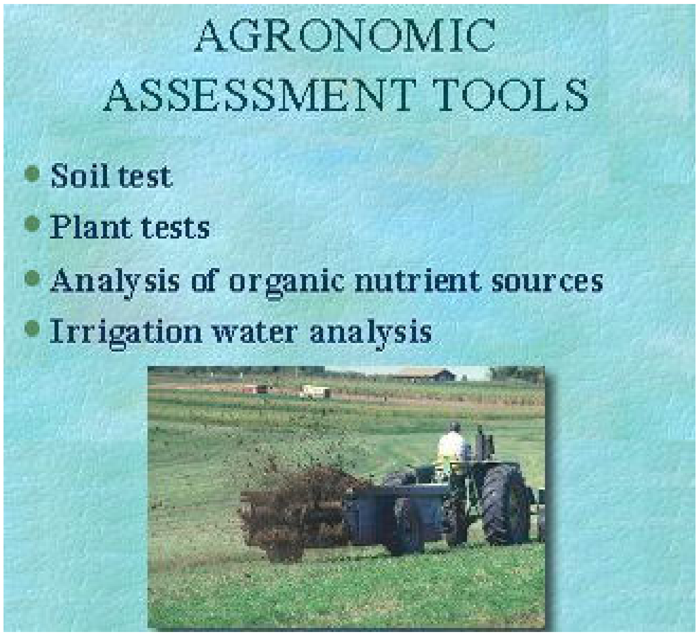
ASSESSMENT TOOLS

- Two categories of assessment tools
  - Agronomic assessment
    - tools that evaluate the nutrient status of the crop or soil
  - Environmental risk assessment
    - tools that evaluate the potential risk of poor nutrient management

Figure 24

- **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):



AGRONOMIC ASSESSMENT TOOLS

- Soil test
- Plant tests
- Analysis of organic nutrient sources
- Irrigation water analysis

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.

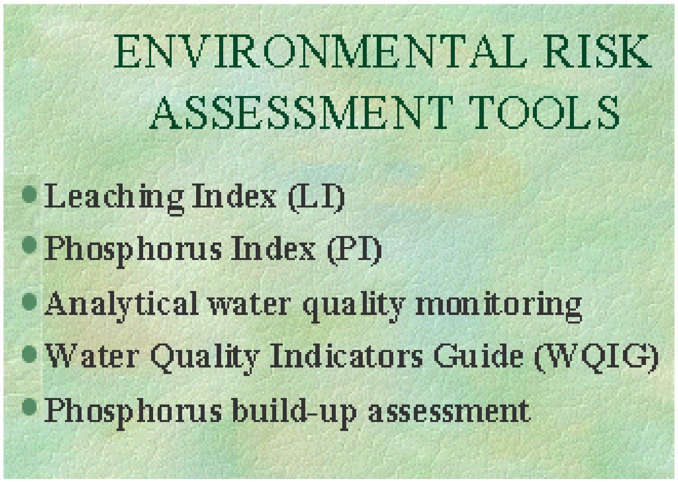
Nitrate test - In certain parts of the country, the pre-plant nitrate test and the pre side-dress nitrate test are used to determine whether or not additional nitrogen is necessary. The deep nitrate test is another tool performed to determine how much nitrogen has already leached below the crop rooting-zone.

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).



ENVIRONMENTAL RISK ASSESSMENT TOOLS

- Leaching Index (LI)
- Phosphorus Index (PI)
- Analytical water quality monitoring
- Water Quality Indicators Guide (WQIG)
- Phosphorus build-up assessment

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.

NUTRIENT MANAGEMENT PLAN COMPONENTS

1. Site maps, including soil map
2. Location of nutrient application restrictions within or near sensitive areas or resources
3. Results of soil, plant, water and organic nutrient source analysis
4. Current or planned plant production system or crop rotation
5. Expected yield
6. Quantification of all important nutrient sources
7. Nutrient budget for the complete plant production system
8. Recommended rate, timing, and methods of application
9. Operation and maintenance of nutrient management plan

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.

2. ***Location of nutrient application restrictions within or near sensitive areas or resources*** - In some cases a few types of sensitive resource areas may be delineated on the maps. Often they are not. Whereas some types of sensitive areas are easily detected – like wetlands, lakes and streams, and public source water protection areas – others such as unique wildlife habitats, deer wintering areas, migration routes, or rare plant species occurrences may not be obvious. State heritage programs, local conservation officers, cooperative extension, and local universities are good sources to contact for learning about where sensitive areas are located.

   The farmer should also ask about recommended restrictions on nutrient application near sensitive areas. This may include set backs required for application of animal manure, reduced application rates, soil conditions that require reduced application rates or restrictions on time of application, or areas with special resource concerns. The producer will remain aware of these areas and modify management accordingly.

3. ***Soil, plant, water, and organic sample analysis results*** - Since nutrient management is based on crop needs and sources of nutrients, an analysis of these factors is essential to know the supplying power of the nutrients and the crop response. These are basic factors to determine the nutrient budget. Soil tests tell the producer the nutrient status of the soil. Plant tissue testing, done at various times during the growing season, shows if the plant is getting adequate nutrients. Testing irrigation water and any biosolids added to the field tell producers the amount of nutrients supplied by these sources.

4. ***Current or planned plant production sequence or crop rotation*** - Nutrient application is based on crop requirements. The sequence of crops will determine needs as well as nutrients carried over from one crop to another.

5. ***Realistic yield goal*** - Crop nutrient requirements are determined based on realistic yield goals. Generally, the higher the yield expectation the higher the nutrient requirement to reach that yield. There are a number of methods available to calculate realistic yield goals (see your Cooperative Extension Service for assistance).

6. ***Quantification of all important nutrient sources*** - Nutrient sources may include, but are not limited to, commercial fertilizer, animal manure and other organic by-products, irrigation water, atmospheric deposition, and legume credits. This information is needed for planners to know what nutrients are available for crop production, when the nutrient will be available, and the type of equipment or management that is required for application.

7. ***A nutrient budget for the complete plant production system*** - A nutrient budget determines the amount of nutrients available from all the sources and compares this to the amount of nutrients required to meet the realistic yield goal. When yield requirements of nutrients exceed the available source then additional nutrients must be brought in to satisfy the crop's requirements. On the other hand, if nutrient supply exceeds crop needs, management measure must be taken to ensure that the excess nutrients are either reduced as inputs or that their application will not cause detrimental effects to the plants, soil, or surrounding environment (see your Cooperative Extension Service for nutrient budget worksheets).

8. ***Recommended rates, timing, and methods of application*** - These are the specifications given to the producer for individual fields or for groups of fields depending on the soil and crop rotation. The specifications for rates are based on the nutrient requirement of the crop (usually taken from soil test recommendations). Timing is determined by crop growth stage and nutrient needs and by the climate conditions that can affect the transformation and transport of nutrients. How the nutrient is applied is based on the form and consistency of the nutrient, soil condition, and potential for movement and loss to the environment.

9. ***Operation and maintenance of the nutrient management plan*** - A number of items need to be reviewed on a regular basis. These include calibration of application equipment, maintaining a safe work environment, review and update of plan elements, periodic soil, water, plant, and organic waste analysis, and monitoring of the resources. This element reminds the producer to continually keep the nutrient management component plan up to date.

CORE 4 ○○●○ 4 MORE ○○○○

Core 4 Principle #3: Pest Management

Pest management is a critical component of conservation planning (Figure 28). It should be used in conjunction with the other CORE 4 principles to address natural resource concerns and to maximize economic returns by enhancing the quantity and quality of agricultural commodities. Pesticides used in pest management can negatively impact non-target plants, animals, and humans. Unintentional exposure may occur in the field and after transport away from the field in soil, water, and air. Ground and surface water quality impairment due to non-point source pesticide contamination is a major concern in many agricultural areas.

Integrated pest management techniques can be effective at reducing the impacts of crop destroying insects such as the potato beetle.

Figure 28

Other forms of pest management also have environmental risks. Cultivation for weed control, burying or burning crop residue for disease and insect control and biological methods of weed, insect and disease control can negatively impact soil, water, air, plants, animals, and humans. To adequately address these environmental risks, conservation planning must include a pest management component that minimizes negative impacts to all identified resource concerns.

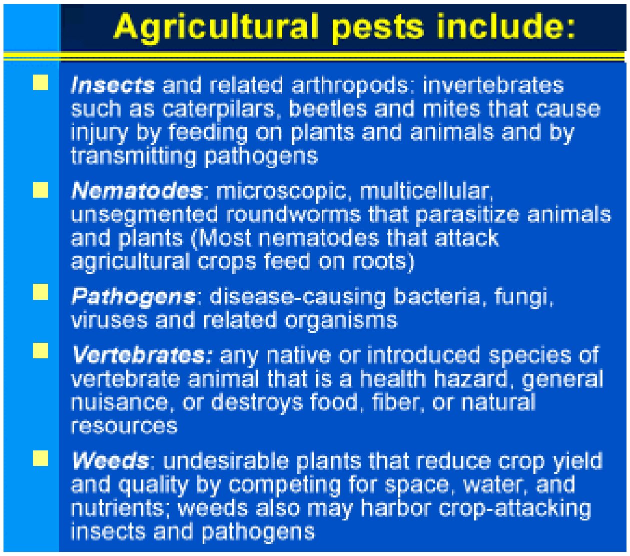
Many pest management principles are very detailed and complex, often requiring formal training to master. NRCS's primary role in pest management is to help producers understand the environmental risks associated with different pest control options so that they can incorporate them into their pest management decision-making process. The ultimate goal is to help producers understand how pest management (including the use of specific pesticides) interrelates with climate, water management, crop management and soil management, so they can implement strategies to minimize environmental hazards related to off-site pesticide movement and its potential impacts on non-target plants, animals, and humans.

Pest Management – Integrated Pest Management

Integrated pest management (IPM) is an approach to pest control that combines biological, cultural and other alternatives to chemical control with the judicious use of pesticides. The objective of IPM is to maintain pest levels below economically damaging levels while minimizing harmful effects of pest control on human health and environmental resources. Pests in the agricultural sense are any organism (plant or animal) judged to be undesirable to the production of crops or animals. Producers typically deal with pests such as insects, nematodes, pathogens, vertebrates, and weeds (Figure 29).

Integrated Pest Management (IPM) depends on a detailed understanding of pest growth and development, and in particular, what causes outbreaks and determines survival.

Figure 29



Agricultural pests include:

- ***Insects*** and related arthropods: invertebrates such as caterpilars, beetles and mites that cause injury by feeding on plants and animals and by transmitting pathogens
- ***Nematodes***: microscopic, multicellular, unsegmented roundworms that parasitize animals and plants (Most nematodes that attack agricultural crops feed on roots)
- ***Pathogens***: disease-causing bacteria, fungi, viruses and related organisms
- ***Vertebrates:*** any native or introduced species of vertebrate animal that is a health hazard, general nuisance, or destroys food, fiber, or natural resources
- ***Weeds***: undesirable plants that reduce crop yield and quality by competing for space, water, and nutrients; weeds also may harbor crop-attacking insects and pathogens

Figure 30

Crops and pests are part of an agroecosystem and the same biological processes found in natural ecosystems govern them. Attempts to control one pest species without regard for the entire ecosystem can disrupt checks and balances between crop plants, pests, beneficials and the physical environment. Failure to appreciate these ecological interactions may increase the severity of pest infestations. IPM therefore depends on a detailed understanding of pest growth and development, and in particular, what causes outbreaks and determines survival (Figure 30).

The term ***integrated*** in IPM means that a broad interdisciplinary approach is taken using scientific principles of plant protection to bring together a variety of management tactics into an overall strategy. The general goals of an IPM strategy are to:

- strive for maximum use of naturally occurring control forces in the pest's environment, including weather, pest diseases, predators, and parasites
- focus first on non-chemical measures that help prevent problems from developing, rather than relying on chemicals to kill infestations after they've occurred
- use chemical pesticides only if close inspection shows they are needed to prevent severe damage

IPM is a decision making process to reduce pest status in a planned, systematic way by keeping their numbers below economically acceptable levels. The essence of integrated pest management is decision making: determining IF, WHEN, WHERE, and WHAT mix of control measures are needed (Figure 31).

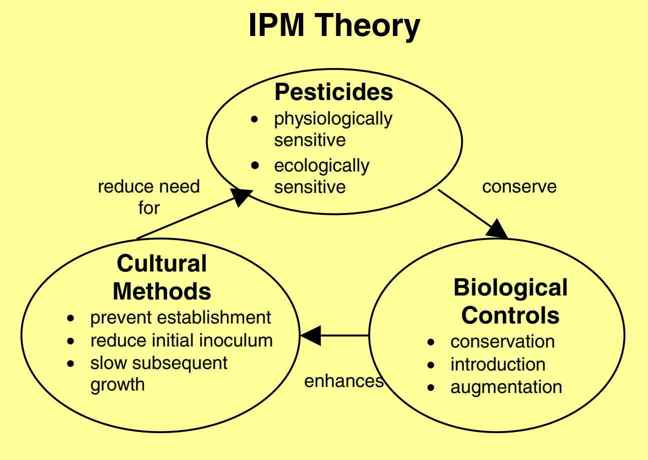


Figure 31

CORE 4 ○○●○ 4 MORE ○○○○

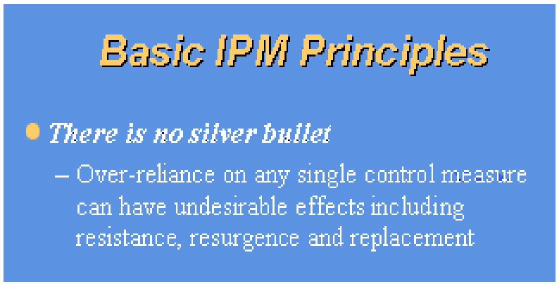
Pest Management – Integrated Pest Management: Resistance

In theory, pests can develop resistance to any type of IPM tactic - biological, cultural, or chemical. Resistance is the innate (genetically inherited) ability of organisms to evolve strains that can survive exposure to pesticides formerly lethal to earlier generations. In practice, resistance occurs most frequently in response to pesticide use (e.g., herbicides, insecticides, and fungicides) (Figure 32).

Figure 32

Insects were the first group of pests to develop pesticide resistant strains. Resurgence is the situation where insecticide application initially reduces an infestation, but soon afterwards the pest rebounds (resurges) to higher levels than before treatment. Replacement, or secondary pest outbreak, is resurgence of non-target pests. It occurs when pesticide is used to control the target pest, but afterwards a formerly insignificant pest replaces the target pest as an economic problem. Based on these characteristics of pests and their interaction with other organisms in the agroecosystem, five common sense principles of IPM have been developed.

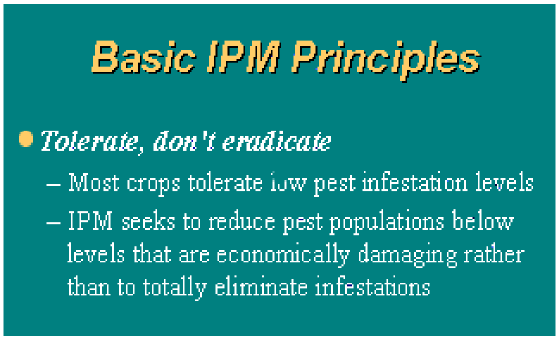
- Principle #1 - There is no silver bullet to pest control (Figure 33)
- Principle #2 - Tolerate, don’t eradicate (Figure 34)
- Principle #3 - Treat the causes of pest outbreaks, not the symptoms (Figure 35)
- Principle #4 - If you kill the natural enemies, you inherit their job (Figure 36)
- Principle #5 - Pesticides are not a substitute for good farming (Figure 37)



Basic IPM Principles

- *There is no silver bullet*
  - Over-reliance on any single control measure can have undesirable effects including resistance, resurgence and replacement

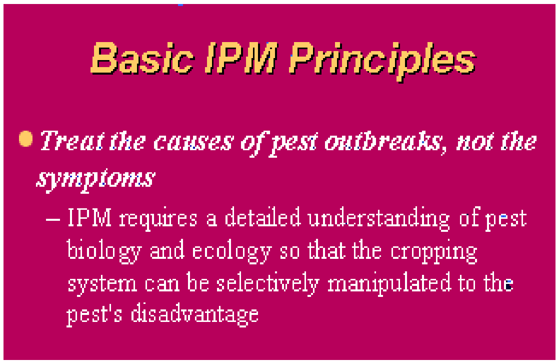
Figure 33



Basic IPM Principles

- *Tolerate, don't eradicate*
  - Most crops tolerate low pest infestation levels
  - IPM seeks to reduce pest populations below levels that are economically damaging rather than to totally eliminate infestations

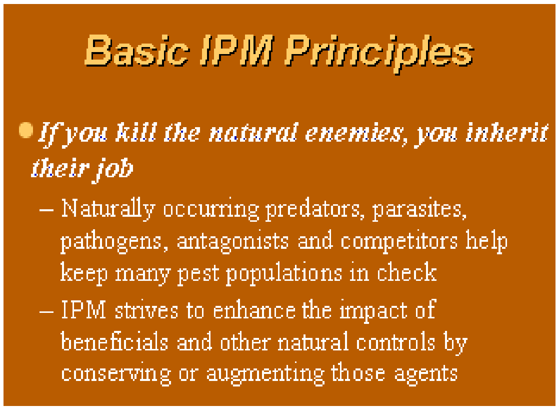
Figure 34



Basic IPM Principles

- *Treat the causes of pest outbreaks, not the symptoms*
  - IPM requires a detailed understanding of pest biology and ecology so that the cropping system can be selectively manipulated to the pest's disadvantage

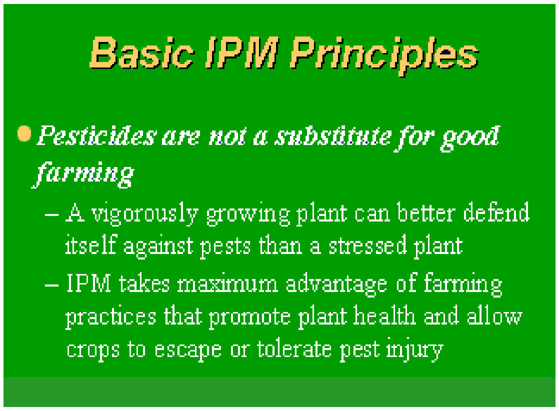
Figure 35



Basic IPM Principles

- *If you kill the natural enemies, you inherit their job*
  - Naturally occurring predators, parasites, pathogens, antagonists and competitors help keep many pest populations in check
  - IPM strives to enhance the impact of beneficials and other natural controls by conserving or augmenting those agents

Figure 36



Basic IPM Principles

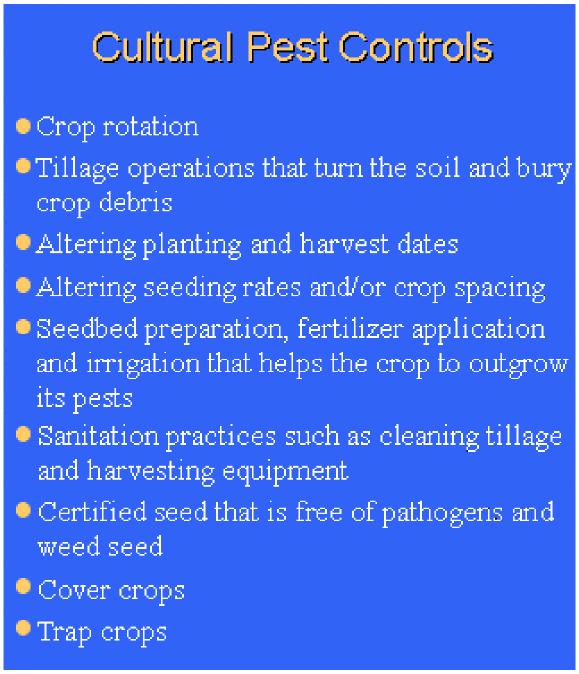
- *Pesticides are not a substitute for good farming*
  - A vigorously growing plant can better defend itself against pests than a stressed plant
  - IPM takes maximum advantage of farming practices that promote plant health and allow crops to escape or tolerate pest injury

Figure 37

Farmers put these IPM principles into practice by following three general steps:

- Step 1 - Use cultural methods, biological controls and other alternatives to conventional chemical pesticides
- Step 2 - Use field scouting, pest forecasting and economic thresholds to ensure that pesticides are used for real (not perceived) pest problems
- Step 3 - Match pesticides with field site features so that the risk of contaminating water is minimized

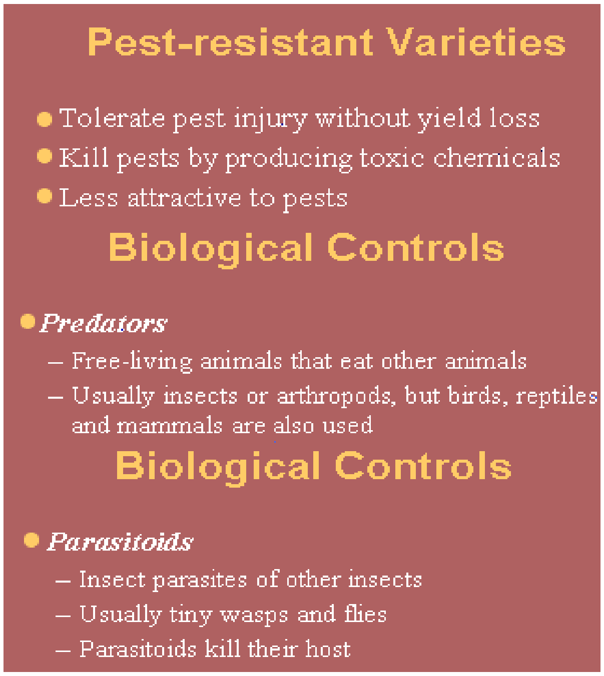
Cultural methods of pest control used in IPM programs are those “good farming” (or “good horticultural”) practices that break the infestation cycle by making the living and non-living environment less suitable for pest survival (Figure 38). Biological controls use living organisms (natural enemies) to suppress populations of other pests (Figure 39). A key principle of IPM is that pesticides should only be used when field examination or scouting shows that infestations exceed economic thresholds. These guidelines differentiate economically insignificant populations from intolerable infestations. Graphically, the decision point to apply pesticide is easy to see and understand, but the real-world determination can be more difficult for a producer (Figure 40).



Cultural Pest Controls

- Crop rotation
- Tillage operations that turn the soil and bury crop debris
- Altering planting and harvest dates
- Altering seeding rates and/or crop spacing
- Seedbed preparation, fertilizer application and irrigation that helps the crop to outgrow its pests
- Sanitation practices such as cleaning tillage and harvesting equipment
- Certified seed that is free of pathogens and weed seed
- Cover crops
- Trap crops

Figure 38



Pest-resistant Varieties

- Tolerate pest injury without yield loss
- Kill pests by producing toxic chemicals
- Less attractive to pests

Biological Controls

- *Predators*
  - Free-living animals that eat other animals
  - Usually insects or arthropods, but birds, reptiles and mammals are also used

Biological Controls

- *Parasitoids*
  - Insect parasites of other insects
  - Usually tiny wasps and flies
  - Parasitoids kill their host

Figure 39

Some individuals in a pest population are genetically adapted to survive applications of a pesticide. Resistance can develop when pesticide application kills susceptible individuals while allowing these naturally resistant individuals to survive. The survivors pass to their offspring the genetically determined resistance trait. If applications of the same pesticide continue, the pest population will be increasingly comprised of resistant individuals and the pesticide will be ineffective.

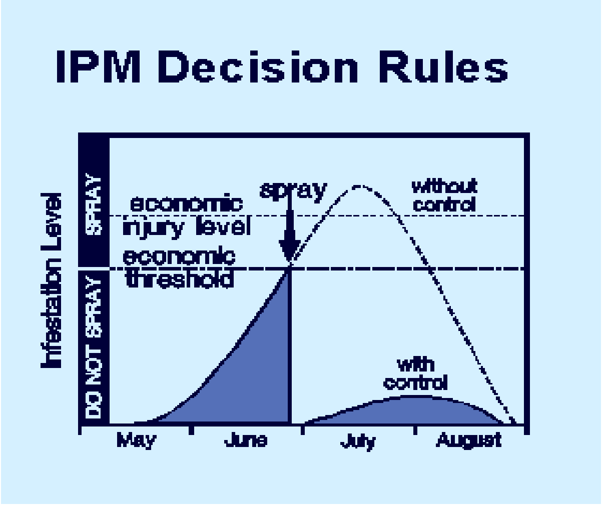
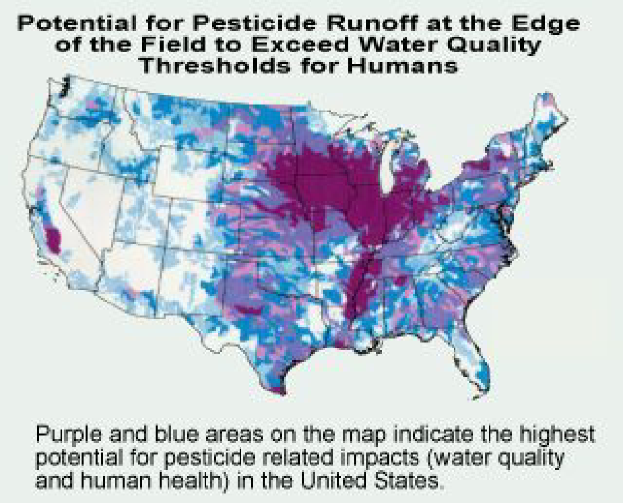


Figure 40

Pest Management – Environmental Risks of Pest Management

Over 1.2 billion pounds of pesticide active ingredients are used annually in the United States in agriculture, forestry, rights-of-way, and by homeowners. A major risk associated with the use of these chemical controls is the pesticide leaving the field in soil, water and air, and negatively impacting non-target plants, animals and humans (Figure 41). Other risks include harming beneficial organisms and risk to personal safety during pesticide application. Many factors govern the potential for pesticide contamination of groundwater and surface water. These factors include soil properties, pesticide properties, hydraulic loading on the soil, and crop management practices.



Potential for Pesticide Runoff at the Edge of the Field to Exceed Water Quality Thresholds for Humans

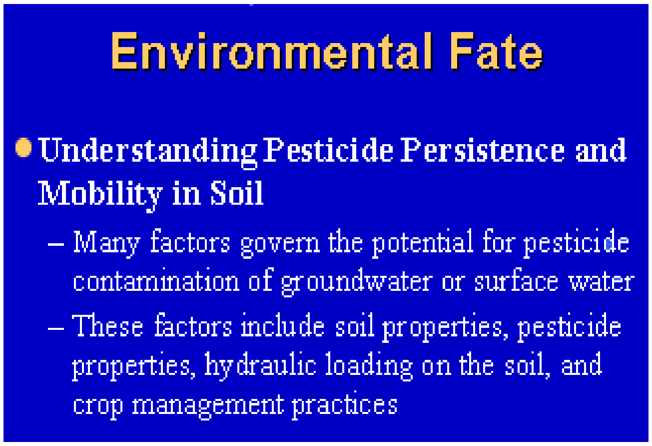
Purple and blue areas on the map indicate the highest potential for pesticide related impacts (water quality and human health) in the United States.

Figure 41

There are many possible environmental fate processes for a pesticide (Figure 42). These processes can be grouped into those that affect persistence, including photodegradation, chemical degradation, and microbial degradation, and those that affect mobility, including sorption, plant uptake, volatilization, wind erosion, runoff, and leaching. Pesticide persistence is often expressed in terms of field half-life. This is the length of time require for one-half of the original quantity to break down or dissipate from the field. Pesticide mobility may result in redistribution within the application site or movement of some amount of pesticide off site. After application, a pesticide has the potential to:

- dissolve in water and be taken up by plants, move in runoff, or leach through the soil column
- volatilize or erode from foliage or soil with wind and become airborne
- attach (sorb) to soil organic matter and soil particles and either remain near the site of deposition or move with eroded soil in runoff or wind

The presence of pesticides in the environment can contribute to adverse ecological effects ranging from fish and wildlife kills to more subtle effects on reproduction and fitness. Due to the toxic effects pesticides have on pests and potentially to the environment and human health, EPA regulates their use and exposure. For example, EPA has set standards for pesticide residues in drinking water for approximately 200 organic chemicals. Concern for these non-target impacts is key to environmentally and



Environmental Fate

- Understanding Pesticide Persistence and Mobility in Soil
  - Many factors govern the potential for pesticide contamination of groundwater or surface water
  - These factors include soil properties, pesticide properties, hydraulic loading on the soil, and crop management practices

Figure 42

economically viable pest management. IPM is therefore aimed at both effective and safe pest control strategies. The goals of IPM are summarized again as follows:

- The pest management component of a conservation plan should enhance crop quality and quantity while minimizing negative impacts to identified resource concerns
- IPM should be utilized where its available
- The conservation plan should be cooperatively developed with whoever makes pesticide recommendations

Core 4 Principle #4: Conservation Buffers

Conservation buffers are areas or strips of land maintained in permanent vegetation to help control pollutants and manage other environmental problems. Buffers are strategically located on the landscape to accomplish many objectives. Although this module only focuses on a few types, there are ten conservation practices commonly thought of as buffers (Figure 43).

Ten common conservation buffer practices

1. Alley cropping
2. Contour buffer strips
3. Cross wind trap strips
4. Field borders
5. Filter strips
6. Grassed waterways with filters
7. Herbaceous wind barriers
8. Riparian forest buffers
9. Vegetative barriers
10. Windbreaks/shelterbelts

Figure 43

Conservation buffers use permanent vegetation to enhance certain ecological functions. For example, the roots of plants stabilize soil and the plant foliage block wind or provide shade. Buffers can vary widely in their vegetation and location on the landscape in order to enhance specific ecological functions that achieve conditions landowners and other stakeholders want. The ecological functions of buffers include creating stable and productive soils, providing cleaner water, enhancing wildlife populations, protecting crops and livestock, enhancing aesthetics and recreation opportunities, and creating sustainable landscapes.

Conservation Buffers – Riparian Forest Buffer

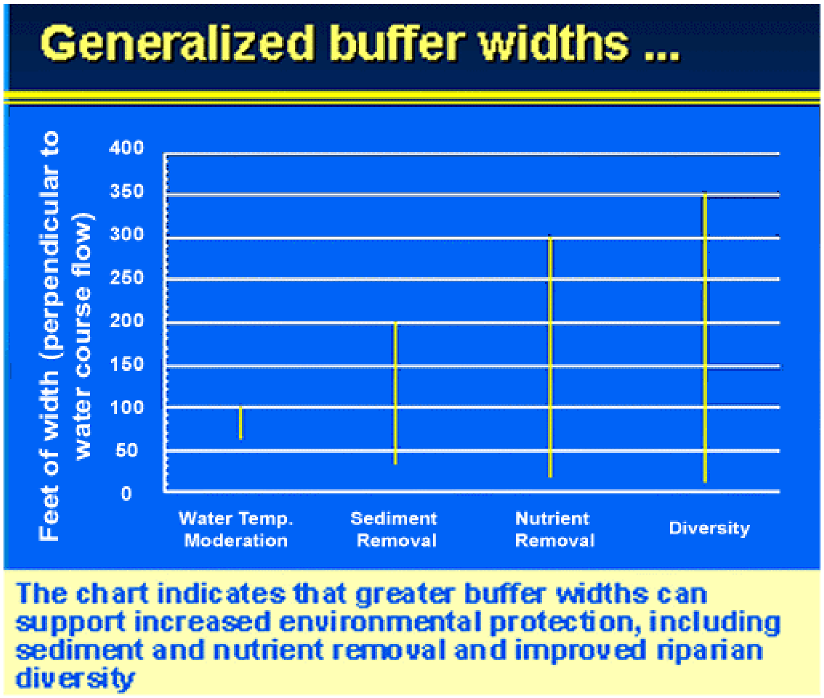

Riparian Forest Buffer

... a CORE conservation practice

Figure 44

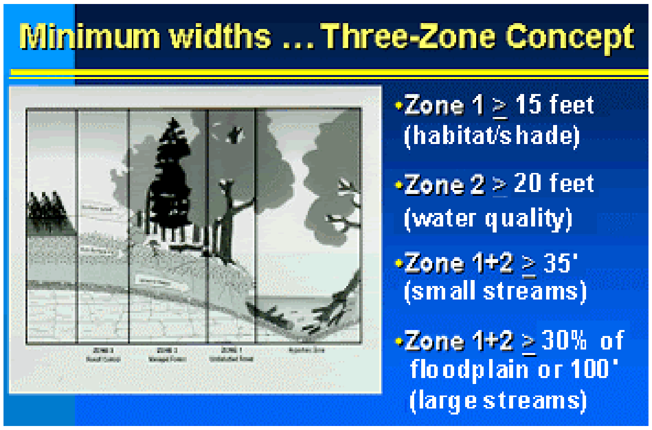
A riparian forest buffer is an area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands (Figure 44). Riparian forest buffers of sufficient width intercept sediment, nutrients, pesticides, and other materials in surface runoff and reduce nutrients and other pollutants in shallow subsurface water flow. Woody vegetation in buffers provides food and cover for wildlife, helps keep water temperatures cooler by shading small streams, and slows out-of-bank flood flows. In addition, the vegetation closest to the stream or waterbody provides litter fall and large woody debris important to aquatic organisms. Also, the woody roots increase the resistance of streambanks and shorelines to erosion caused by high water flows or waves.

For riparian forest buffers to achieve specific purposes, they must be properly located and sized (width, length, area) in relation to the stream or waterbody (Figure 45 shows generalized buffer widths for different purposes). The general widths listed in the figure are based on the average findings from many scientific studies. The right buffer width for a given purpose actually may vary from stream to stream based on stream size and other factors. Because of this variability in buffer width requirements from place to place, a 3-zone minimum buffer is sometimes used as a minimum guideline when planting a buffer where there is little or none.


Generalized buffer widths ...

The chart indicates that greater buffer widths can support increased environmental protection, including sediment and nutrient removal and improved riparian diversity

Figure 45



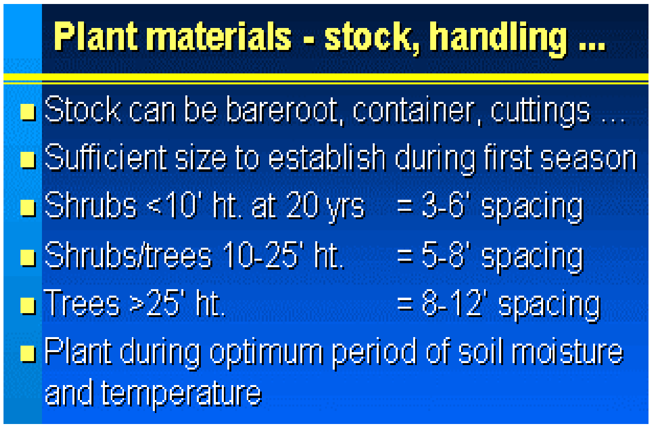
Minimum widths … Three-Zone Concept

- Zone 1 ≥ 15 feet (habitat/shade)
- Zone 2 > 20 feet (water quality)
- Zone 1+2 ≥ 35' (small streams)
- Zone 1+2 ≥ 30% of floodplain or 100' (large streams)

Figure 46

The 3-zone minimum buffer concept (Figure 46) starts with a zone (identified as zone 1) that begins at the normal water line, or at the upper edge of the active channel (or top of the bank), and extends a minimum of distance of 15 feet, measured horizontally on a line perpendicular to the watercourse or waterbody. Bank vegetation along practically all streams plays a crucial role in reducing soil erosion and land loss as well as performing other functions; one or both sides of a stream may need treatment where a vegetated buffer is absent from zone 1. To reduce excess amounts of sediment, organic material, nutrients, and pesticides in surface runoff and to reduce excess nutrients and other chemicals in shallow ground water flow, zone 2 is needed. On small streams, zone 2 will begin at the edge and up-gradient of zone 1 and extend a minimum distance of 20 feet. For larger streams or waterbodies, the minimum combined widths of zones 1 and 2 is 100 feet or 30 percent of the geomorphic floodplain, whichever is less. The minimum length of zones 1 and 2 must match the adjacent dimension of the source field or area. For greatest effect, the buffer length can be extended along the entire waterbody within the ownership, or beyond if possible. Zone 3, regardless of practices used, is an area of sufficient size identified and created to control concentrated flow or mass soil erosion that may degrade zones 1 and 2. A variety of practices may apply such as critical area planting, mulching, use exclusion, and filter strips.

When selecting plant materials for forest buffers, it is important to use trees and shrubs suited to the site and the intended purpose. **Favor tree and shrub species that are locally native and match the potential of the site**. If possible, use species that meet the specific requirements of fish and other aquatic organisms for food, habitat, migration and spawning. Establishing a forest buffer also requires consideration of proper planting procedures, site preparation, and operation and maintenance (Figure 47).



Plant materials - stock, handling ...

- Stock can be bareroot, container, cuttings ...
- Sufficient size to establish during first season
- Shrubs <10' ht. at 20 yrs = 3-6' spacing
- Shrubs/trees 10-25' ht. = 5-8' spacing
- Trees >25' ht. = 8-12' spacing
- Plant during optimum period of soil moisture and temperature

Figure 47

Conservation Buffers – Grassed Waterway with Vegetative Filter


Grassed Waterway with Vegetative Filter

A grassed conveyance can protect against erosion and helps to filter sediment and pollutants carried in runoff.

Figure 48

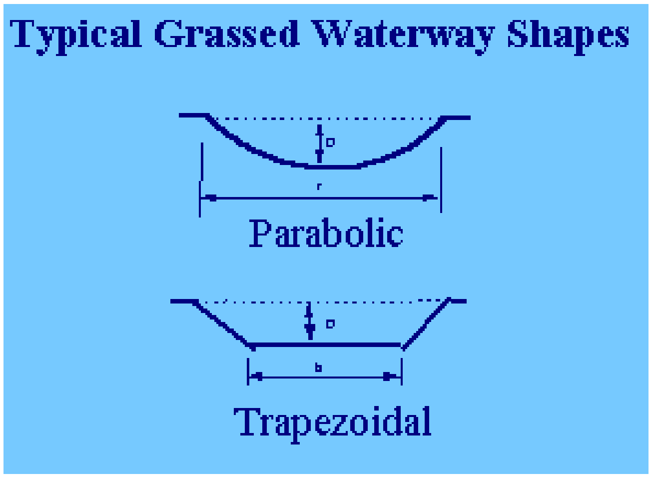


Figure 49

A grassed waterway is a natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff. The primary purposes of a grassed waterway are to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water quality (Figure 48). The additional benefits of grassed waterways include wildlife habitat, corridors connection, vegetative diversity, noncultivated strips of vegetation, and improved aesthetics.

Design considerations for grassed waterways include soil conditions and erodibility, slope, vegetative cover, maintenance, and channel shape (Figure 49). NRCS's National Handbook of Conservation Practices and Engineering Field Handbook are two references that provide guidance in how to plan and design a grassed waterway for its primary purposes. The basic design can be modified to further enhance its performance. For example, providing an additional vegetative width to the grassed waterway allows the waterway to serve as a filter strip/buffer (Figure 50).

As with any filter strip, to be effective in reducing sediment loading from the adjacent field, the runoff must enter a filter strip along the grassed waterway as sheet flow. Vegetation in the grassed waterway must be well established to withstand velocities that it is designed to accommodate. In some areas special measures, such as mulching or flow diversion, are needed to ensure that vegetation has a chance to establish.

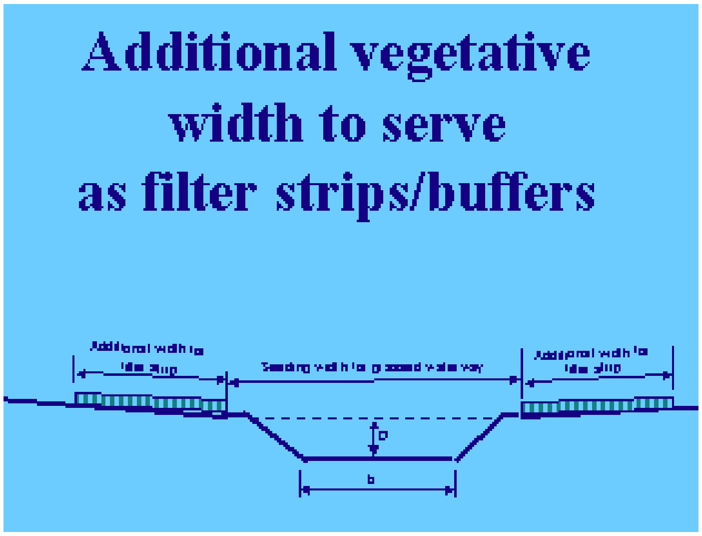


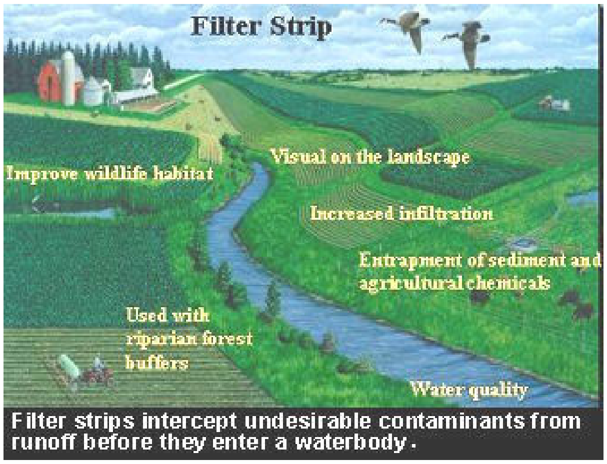
Figure 50

CORE 4 ○○○● 4 MORE ○○○○

Conservation Buffers –Filter Strip

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff and to maintain or improve water quality (Figure 51). Filter strips intercept undesirable contaminants from runoff before they enter a waterbody. They provide a buffer between contaminant sources, such as crop fields, and waterbodies, such as streams and ponds. Filter strips slow the velocity of water, allowing the settling out of suspended soil particles, infiltration of runoff and soluble pollutants, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. The mechanisms of filter strip function can vary according to the characteristics of a pollutant (Figures 52–54). Secondary benefits of filter strips may also include:

- Forage - for farm use or as cash crop
- Field borders
- Turnrows and headlands
- Access
- Aesthetics



Filter strips intercept undesirable contaminants from runoff before they enter a waterbody.

Figure 51

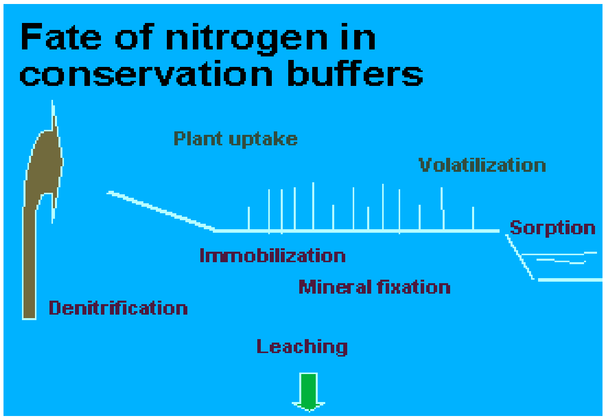


Figure 52

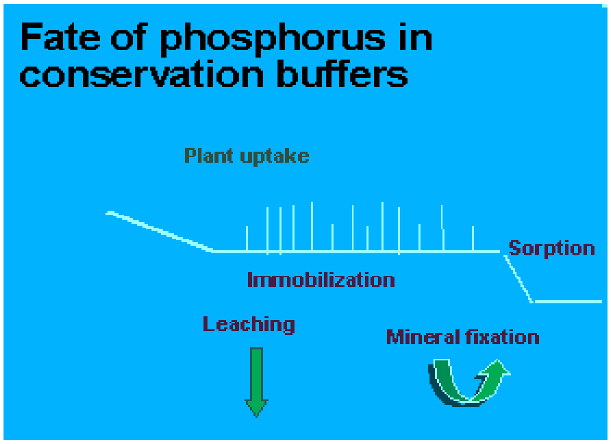


Figure 53

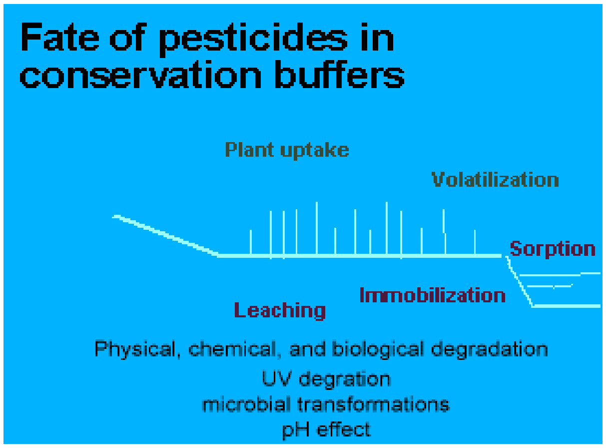


Figure 54

Filter strips apply to lower edges of cropland fields where contributions of pollutants may move off the cropland area. They can also be used above conservation practices, such as ponds, drainageways, and terraces, to reduce the load of sediment and other contaminants moving into the practice areas. The slope of the filter and the soil of the filter area impact the overall performance. Steeper slopes increase flow velocity and shorten the time the contaminant material carried in the runoff, both particulate and soluble, has an opportunity to interact with the vegetation and soil in the filter area. In most filter systems the greater the flow length (filter width) of filter area provides the greater entrapment and removal of contaminants. Most practical designs are based on contaminant removals of more than 50 to 60 percent.

Operation and maintenance requirements for filter strips are minimal. To allow proper functioning and performance, it is recommended that maintenance include the following:

- Provide for shallow, sheet flow into the filter
- Repair rills and redirect concentrated flow
- Remove sediment accumulations
- Harvest biomass
- Control weeds
- Integrate other conservation practices

CORE 4 ○○○● 4 MORE ○○○○

Conservation Buffers – Vegetative Barriers

Vegetative barriers (also referred to as grass hedges) are narrow, parallel strips of stiff, erect, dense grass planted close to the contour (Figure 55). These barriers cross concentrated flow areas at convenient angles for farming. This practice differs from other conservation buffers because vegetative barriers are managed in such a way that any soil berms that develop are not smoothed out during maintenance operations. Vegetative barriers can be used for the following purposes (Figure 56):

- Control sheet and rill erosion, trap sediment, and facilitate benching of sloped cropland
- Control rill and gully erosion and trap sediment in concentrated flow areas
- Trap sediment at the bottom of fields and at the ends of furrows
- Improve the efficiency of other conservation practices

Parallel barriers divide field into short tilled strips, making tillage impact greater.

Figure 55

Sediment deposited upslope of barriers and soil moved from shoulders by tillage gradually level flow areas.

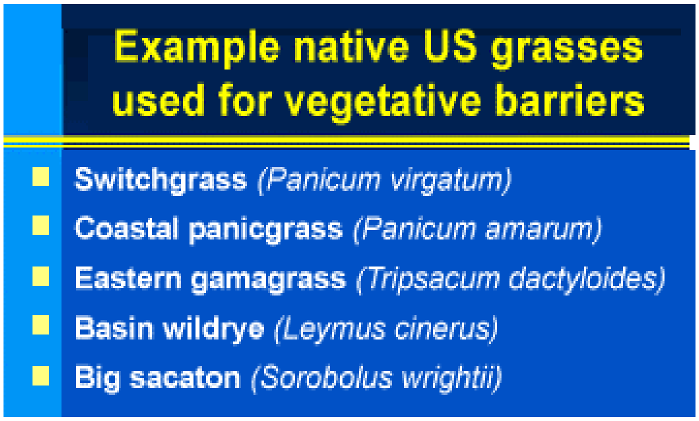
Figure 56

Coarse, stiff, hedge-forming grasses can withstand high water flows that would bend and overtop finer vegetation. They retard flow velocity and spread out surface runoff. Reduced velocity prevents scouring, causes deposition of eroded sediment, and lessens ephemeral gully development. Vegetative barriers can also disperse flow where water enters other types of conservation buffers, increasing the efficiency of these practices. Placing vegetative barriers on the landscape divides fields into cropped and vegetative strips. Under tillage, soil moves downslope from the upper part of each cropped area and is deposited upslope of the next barrier, gradually leveling the tilled area and creating small terraces (Figure 57). The practice can be applied to all eroding areas, including but not limited to cropland, pastureland, rangeland, feedlots, mined land, gullies, and ditches.

Vegetation should be established that has a density of at least 50 stems per square foot in all barriers. A barrier should be designed to be at least 3 feet wide. If barrier vegetation is so tall-growing that mowing is needed to minimize crop shading, barriers may be made wider to accommodate available mowing equipment. Selection of vegetative species should consider characteristics such as stem strength, plant density, invasive growth, and whether it is a host for insects and disease pests in the region. Certain native and exotic (non-native) grass species have proven to be effective for establishing vegetative barriers; but, some species of non-native plants can become pests that may require expensive eradication. The safest approach is to use native plant species only (Figure 58). Moreover, many native grasses are more chemical resistant and will not die from runoff from the adjacent agricultural field. Some nurseries can provide information on their native vs. non-native plants as well as what risks may exist for the non-native plant species to spread invasively and cause problems.


Soil thrown into vegetative barriers by tillage gradually forms small terraces.

Figure 57


Example native US grasses used for vegetative barriers

- **Switchgrass** *(Panicum virgatum)*
- **Coastal panicgrass** *(Panicum amarum)*
- **Eastern gamagrass** *(Tripsacum dactyloides)*
- **Basin wildrye** *(Leymus cinerus)*
- **Big sacaton** *(Sorobolus wrightii)*

Figure 58

Conservation Buffers – Wind Control Buffers

Vegetation can also be used as a buffer to protect soil, crops, animals, and waterbodies from wind (Figure 59). Three common conservation buffers for wind control are **cross wind traps**, **herbaceous wind barriers**, and windbreaks. Cross wind traps are plantings resistant to wind erosion and grown perpendicular to the prevailing wind erosion direction.

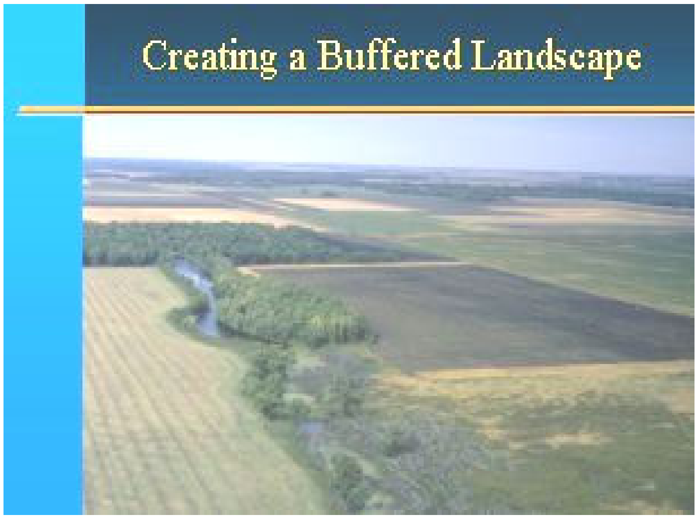

Creating a Buffered Landscape

Figure 59

Cross wind traps strips entrap wind-borne sediment and establish a stable area to resist wind erosion (Figure 60). Trap strips are designed to be 12 to 15 feet wide, 1 to 2 feet high, consist of 50 percent or greater vegetation, and maintain 50 to 75 per square foot stem density. Herbaceous wind barriers are tall grass and other non-woody plants established in 1- to 2-row narrow strips spaced across the field perpendicular to the normal wind direction.


Buffer System in New York

Trees and other tall and dense vegetation planted at the edge of fields can protect against wind erosion and entrap windborne soil.

Figure 60

Herbaceous wind barriers reduce wind velocity across the field and intercept wind-borne soil particles. Species selected for perennial herbaceous wind barriers should consist of stiff, erect grasses and forbs adapted to local soil and climate conditions. Barrier species must have sufficient strength to remain erect against anticipated high velocity wind and waterflows. They should also have good leaf retention and pose minimum competition to adjacent crops. Additional desirable characteristics include tolerance to sediment deposition, long life expectancy, and highly competitive with weeds. NRCS's Field Office Technical Guide is an excellent resource for plant species information.

Windbreaks or shelterbelts are plantings of single or multiple rows of trees or shrubs that are established to protect or shelter nearby leeward areas from troublesome winds. These plantings are used to reduce wind erosion, protect growing plants, improve irrigation efficiency, protect structures and livestock, provide wildlife habitat, improve aesthetics, provide tree or shrub products, and control views and lessen noise. Proper design is essential for wind breaks to operate effectively. Windbreak height (H) is the most important factor determining the downwind area of protection. Windbreaks reduce wind speed for 2 to 5 times the height of the windbreak (2H to 5H) on the upwind side and up to 30H on the downwind side of the barrier.

Although the height of the windbreak determines the extent of the protected area downwind, the length of a windbreak determines the total area of protection. For maximum efficiency, the uninterrupted length should exceed the height by at least 10:1. Windbreak density is the ratio of the solid portion of the barrier to the total area of the barrier. The more dense the windbreak, the less wind passes through. Layout is another design consideration and windbreaks are most effective when oriented at right angles to prevailing winds. Figures 61 and 62 show before-and-after field photos of a real world example of wind buffer design and implementation.

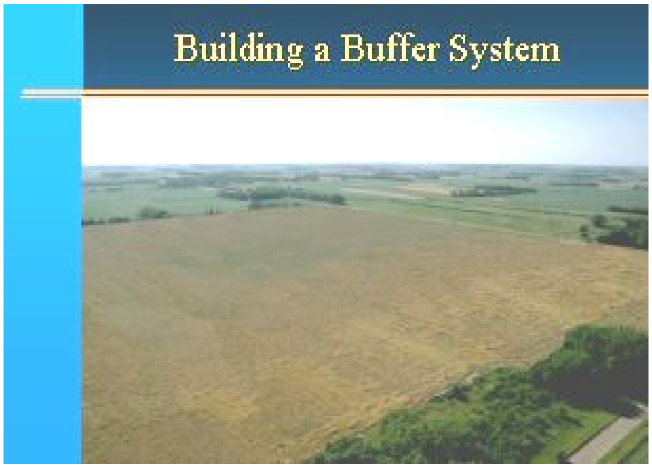

Building a Buffer System

Figure 61

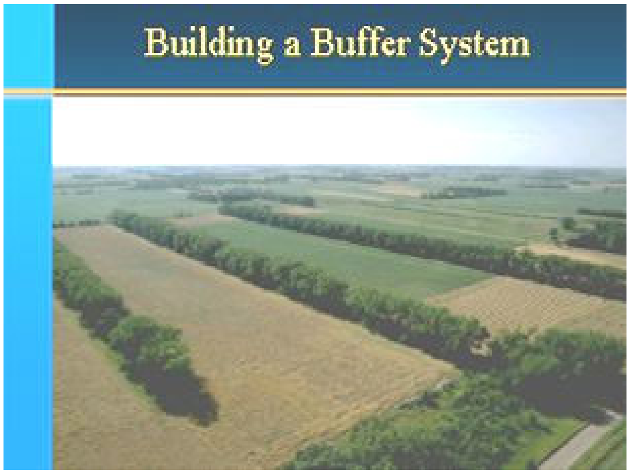

Building a Buffer System

Figure 62

It’s important to keep in mind that conservation buffers are only part of an overall system of conservation practices that control the source and transport of contaminants that may be lost as part of the agricultural production system. Other CORE 4 conservation practices and management techniques, such as crop residue management, nutrient and pest management, and timing of tillage and chemical applications maybe just as important as means to prevent initial contaminant movement from the site. Therefore, each CORE 4 practice discussed in this module is most effective when integrated into an overall management system that addresses all natural resource concerns and the objectives of the landowner or operator.

PART TWO: (FOUR MORE) SUPPLEMENTAL AGRICULTURAL BMPS

The CORE 4 practices discussed in the Part One of the module are most effective when integrated into an overall management system that addresses all natural resource concerns and the objectives of the landowner or operator. Other agricultural management measures, beyond the CORE4 practices already discussed, may provide additional benefits to the farmer and the environment. These measures can be considered as part of a comprehensive management plan. The supplemental measures include irrigation water management, animal grazing management, animal feeding operations (AFOs) management, and erosion and sediment control (Figure 63).

Four agricultural practices from EPA's *Nonpoint Management Measures*

- Irrigation water management
- Grazing management
- Animal feeding operations management
- Erosion and sediment control

Figure 63

CORE 4 ○○○○ 4 MORE ●○○○

Principle #5: Irrigation Water Management

A primary concern for irrigation water management is the discharge of salts, pesticides, and nutrients to ground water and discharge of these pollutants plus sediment to surface water. Effective and efficient irrigation begins with a basic understanding of the relationships among soil, water, and plants (Figure 64). The amount of water the plant needs, its consumptive use, is equal to the quantity of water lost to evapotranspiration. Due to the inefficiencies in the delivery of irrigated water (e.g., evaporation, runoff, wind drift, and drip percolation losses), the amount of water needed for irrigation is greater than the consumptive use. In arid and semi-arid regions, salinity control may be a consideration, and additional water may be needed to flush the salts from the root zone.

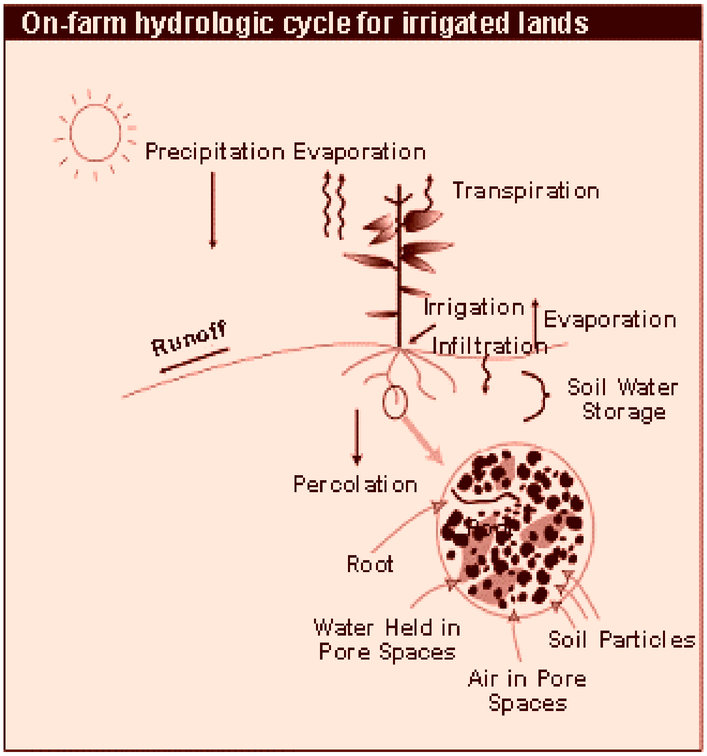


Figure 64

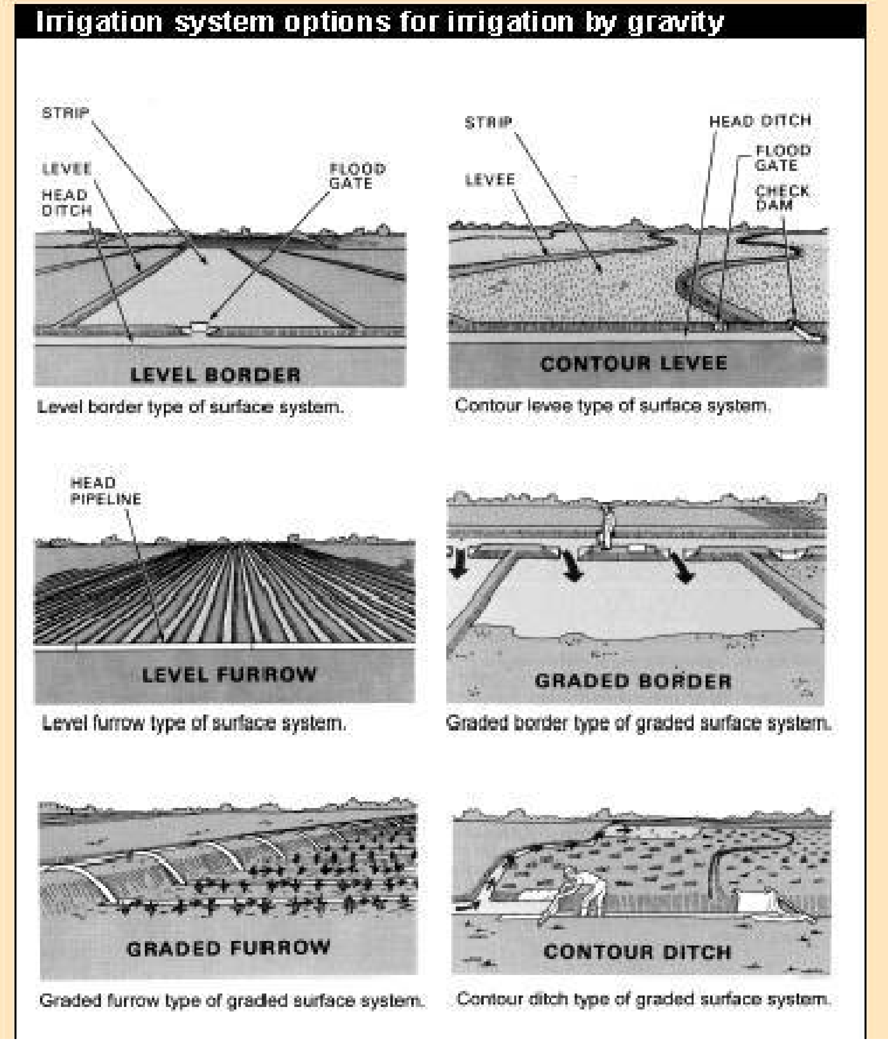
Irrigation systems (Figure 65) consist of two basic elements: the transport of water from its source to the field, and the distribution of transported water to the crops in the field. Transport of irrigation water from the source of supply to the irrigated field via open canals can be a source of water loss if the canals are not lined. In many soils, unlined canals lose water through evaporation and seepage in bottom and side walls. Seepage water can percolate into the ground water, carrying with it any soluble pollutants in the soil and creating potential for pollution of ground or surface water.


Center-pivot irrigation systems produce these distinctive circular patterns on the agricultural landscape.

Figure 65

Factors that are typically considered in selecting an appropriate irrigation method include land slope, water intake rate of the soil, water tolerance of crops, and wind. Additionally, the chemical characteristics of the soil and the quantity and quality of the irrigation water will determine whether irrigation is a suitable management practice that can be sustained without degrading the soil or water resources.

Irrigation system options for irrigation by gravity



Level border type of surface system.

Contour levee type of surface system.

Level furrow type of surface system.

Graded border type of graded surface system.

Graded furrow type of graded surface system.

Contour ditch type of graded surface system.

Figure 66

There are four basic methods of applying irrigation water: surface, sprinkler, trickle, and subsurface. Gravity-based surface systems use canals or ditches to transport the water to the fields (Figure 66). Pressure-based systems, such as sprinklers, depend on pumping water to the fields and applying the water with a variety of equipment types (Figure 67, next page). Micro-irrigation systems, including trickle and subsurface methods, are designed to apply the required water needs at the root zone of each plant, thus minimizing unnecessary losses to the surrounding soil or non-target plants (Figure 68, next page). The following table describes the

Figure 4f-8. Typical types of sprinkler irrigation systems (Turner, 1980).

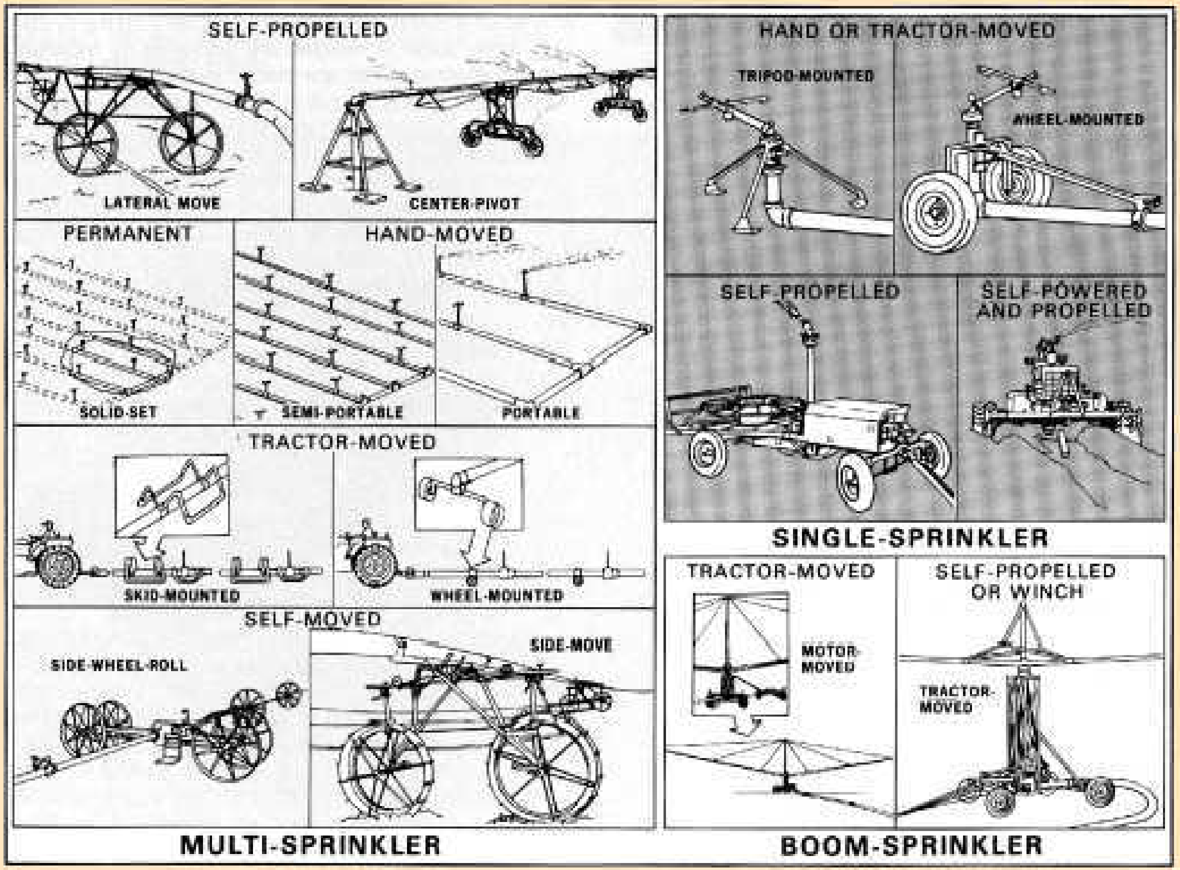
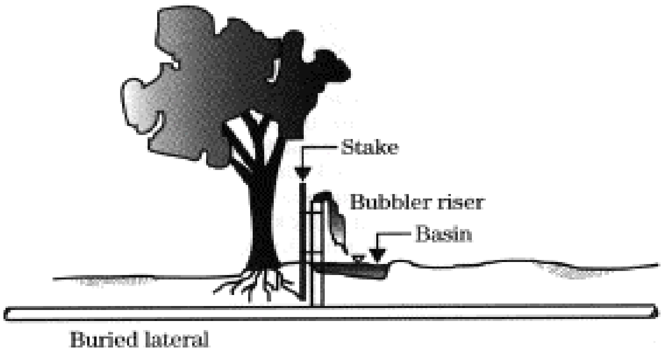


Figure 67

Basin bubbler system



Precision irrigation techniques, such as this bubbler system, conserve water. The system delivers water to each individual plant and is commonly used for crops like fruit trees.

Figure 68

common types of irrigation systems and the major features of each (Figure 69, next page). The advantages and disadvantages of the various types of irrigation systems are described in a number of existing documents, manuals, videos, and software assembled by the US Department of Agriculture.

Irrigation System Type	Major Features of System
Gravity-Level Basins	Large flow rates over short periods to flood entire field or basin. Level fields surrounded by low dike or levee. Best for soils with low to medium water intake rate.
Gravity-Contour Levees	Similar to level basins except for rice. Small dikes or levees constructed on contour. For rice, ponding is maintained. Best for soils with very low intake rate.
Gravity-Level Furrows	Large flow rates over short periods. Level fields. End of furrow or field is blocked to contain water. Best for soils with moderate to low water intake rate and moderate to high available water capacity.
Gravity-Graded Borders Controlled surface flooding.	Field divided into strips bordered by parallel dikes or border ridges. Water introduced at upper end.
Gravity-Graded Furrows	Like graded borders, but only furrows are covered with water. Water distribution via vertical and lateral infiltration. Water application amount is a function of intake rate of soil, spacing of furrows, and length of field. Heavy soils (small pores sizes) provide slower infiltration and greater lateral movement.
Gravity-Contour Ditches Controlled surface flooding.	Water discharged with siphon tubes, over ditch banks, or from gated pipes located upgradient and positioned across the slope on contour. Sheet flow is goal.
Pressure-Periodic Move Sprinkler	Sprinkler is operated in a fixed location for a specified period of time, then moved to the next location. Many design options including hand-moved laterals, side-roll laterals, end-tow laterals, hose-fed (pull) laterals, guns, booms, and perforated pipe.
Pressure- Fixed or Solid-Set Sprinkler	Laterals are not moved, but one or more sections of sprinklers are cycled on and off to provide coverage of entire field over time.
Pressure-Continuous Move Sprinkler	Center pivot (irrigates in circular patterns, or rectangular with end guns or swing lines) or linear (straight lateral irrigates in rectangular patterns) move continuously to irrigated field. Multiple sprinklers located along the laterals.
Pressure-Traveling Gun Sprinkler	High-capacity, single-nozzle sprinkler fed by flexible hose. Hose is dragged or on a reel. Gun is guided by cable, and moved from field to field. Best for soils with high water intake rates.
Pressure-Traveling Boom Sprinkler	Similar to traveling gun, except a boom with several nozzles is used.
Micro/Pressure-Point Source Emitters	Frequent, low-volume, low-pressure applications through small tubes and drop, trickle, or bubbler emitters. Water must be filtered. Used for orchards, vineyards, ornamental landscaping. Emitters discharge from 0.5 to 30 gallons per hour.
Micro/Pressure-Line Source Emitters	Frequent, low-volume, low-pressure applications through surface or buried tubing that is porous or has uniformly spaced emitter points. For permanent crops, but also vegetables, cotton, melons.
Micro/Pressure-Basin Bubblers	Water applied via risers into small basins adjacent to plant. Bubblers discharge less than 60 gallons per hour. Water filtration not required. Orchards and vineyards. Best for medium to fine textured soils.
Micro/Pressure-Spray or Mini-Sprinklers	Water applied as spray droplets from small, low-pressure heads. Wets a greater area (2 to 7 feet in diameter) than drop emitters. Discharges less than 30 gallons per hour.
Subirrigation	Manage water table by providing subsurface drainage, providing controlled drainage, and irrigating via buried laterals.

Figure 69

Ultimately, cost-effective irrigation matches crop needs while limiting erosion from applied water, reducing the movement of pollutants from land into ground or surface waters, and minimizing wasted time, energy, and water (Figure 70). These goals can be achieved through consideration of the following aspects of irrigation systems:

1. Irrigation scheduling
2. Efficient application of irrigation water
3. Efficient transport of irrigation water
4. Use of runoff or tailwater
5. Management of drainage water

Irrigation water management uses effective techniques to minimize wasted time, energy, and water.

Figure 70

1. ***Irrigation scheduling*** is the use of water management strategies to prevent over-application of water while minimizing yield loss from water shortage or drought stress. Irrigation scheduling should be based on knowing the daily water use of the crop, the water-holding capacity of the soil, and the lower limit of soil moisture for each crop and soil, and measuring the amount of water applied to the field. Therefore, proper irrigation scheduling depends on daily accounting of the cropland field water budget. The tools required to complete this budget include water measuring devices (e.g., irrigation water meter, flume, or weir) and soil and crop water use data (reported in USDA publications).

2. ***Efficient application of irrigation water*** ensures proper use and distribution of water, minimizes runoff or deep percolation, and minimizes soil erosion. The method of application should be suitable to the site-specific conditions of the farm (slopes, soils, types of crop, climate, etc.). The selected systems should also be properly designed and operated. Conservation treatments such as land leveling, irrigation water management, reduced tillage, and crop rotations can be used to help control irrigation-induced erosion.

3. ***Efficient transport of irrigation water*** requires that water transportation systems be designed and managed in a manner that minimizes evaporation, seepage, and flow-through water losses from canals and ditches. Delivery and timing need to be flexible enough to meet varying plant water needs throughout the growing season. Water transportation improvements can include ditch and canal lining, installation of piping systems, and other water control structures. Irrigation water withdrawals in regions of the country where salmon and trout are found should particularly try to prevent fish from swimming up irrigation ditches and dying during their spawning runs.

4. ***Use of runoff or tailwater*** is the process of capturing irrigation runoff and reusing it for irrigation needs. This practice can reduce the amount of water diverted for irrigation, reduce the discharge of pollutants such as suspended sediment and farm chemicals, and increase overall system efficiency. A tailwater recovery system is needed to collect, store, and transport irrigation tailwater for reuse in the farm irrigation system (Figure 71, next page).

5. ***Management of drainage water*** is intended to reduce deep percolation, move tailwater to the reuse system, reduce erosion, and help control adverse impacts on surface and ground water. There are several practices to accomplish this, including:

   a. ***Filter strips and buffers*** - a strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff.
   b. S***urface drainage field ditch*** - a graded ditch for collecting excess water in a field.
   c. ***Subsurface drain*** - a conduit, such as corrugated plastic pipe, installed beneath the ground surface to collect and/or convey drainage water.
   d. ***Water table control*** - controlled through proper use of subsurface drains, water control structures, and water conveyance facilities for the efficient removal of drainage water and distribution of irrigation water.

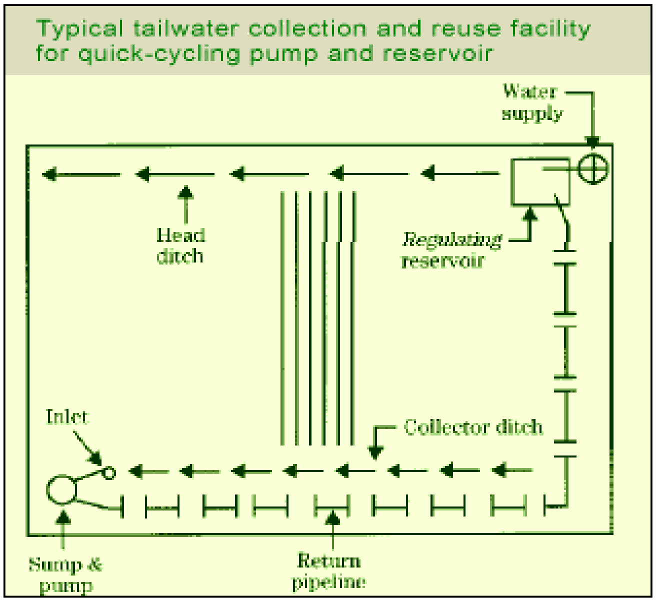


Figure 71

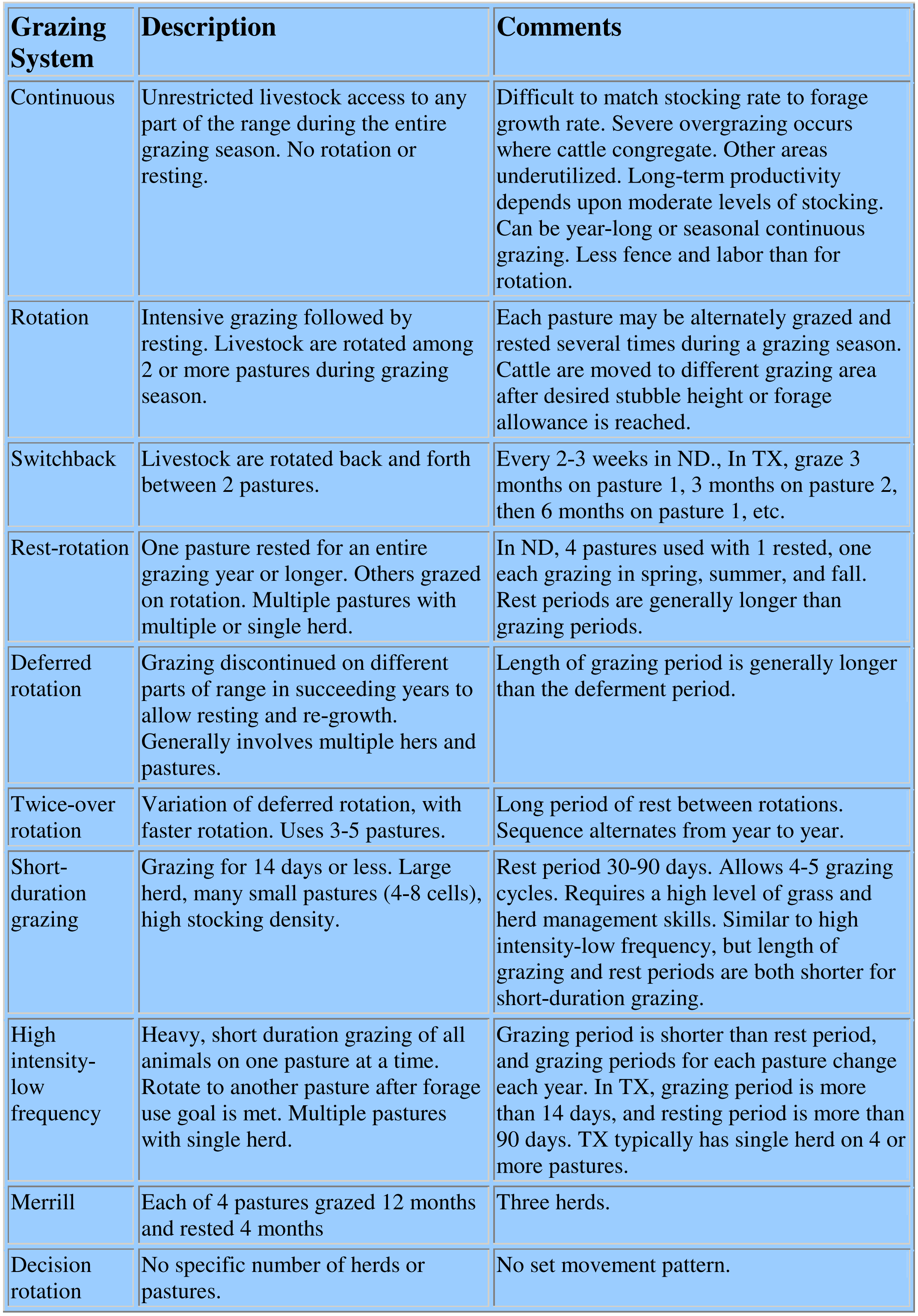
CORE 4 ○○○○ 4 MORE ○○●○

Principle #6: Grazing Management

Grazing management strategies are applied to activities on range, irrigated and non-irrigated pasture, and other grazing lands used by domestic livestock (Figure 72). Range refers to lands such as natural grasslands, savannas, wetlands, and certain shrub lands. In most cases, range supports native vegetation that is extensively managed through the control of livestock rather than agronomy practices, such as fertilization, mowing, or irrigation. Pastures are improved lands that have been seeded, irrigated, and fertilized and are primarily used for the production of adapted, domesticated forage plants for livestock. There is a wide range of grazing systems for rangeland and pastures that managers may select from (Figure 73, next page).

Grazing management techniques attempt to protect land and water and optimize production of domesticated livestock.

Figure 72



Grazing System	Description	Comments
Continuous	Unrestricted livestock access to any part of the range during the entire grazing season. No rotation or resting.	Difficult to match stocking rate to forage growth rate. Severe overgrazing occurs where cattle congregate. Other areas underutilized. Long-term productivity depends upon moderate levels of stocking. Can be year-long or seasonal continuous grazing. Less fence and labor than for rotation.
Rotation	Intensive grazing followed by resting. Livestock are rotated among 2 or more pastures during grazing season.	Each pasture may be alternately grazed and rested several times during a grazing season. Cattle are moved to different grazing area after desired stubble height or forage allowance is reached.
Switchback	Livestock are rotated back and forth between 2 pastures.	Every 2-3 weeks in ND., In TX, graze 3 months on pasture 1, 3 months on pasture 2, then 6 months on pasture 1, etc.
Rest-rotation	One pasture rested for an entire grazing year or longer. Others grazed on rotation. Multiple pastures with multiple or single herd.	In ND, 4 pastures used with 1 rested, one each grazing in spring, summer, and fall. Rest periods are generally longer than grazing periods.
Deferred rotation	Grazing discontinued on different parts of range in succeeding years to allow resting and re-growth. Generally involves multiple hers and pastures.	Length of grazing period is generally longer than the deferment period.
Twice-over rotation	Variation of deferred rotation, with faster rotation. Uses 3-5 pastures.	Long period of rest between rotations. Sequence alternates from year to year.
Short-duration grazing	Grazing for 14 days or less. Large herd, many small pastures (4-8 cells), high stocking density.	Rest period 30-90 days. Allows 4-5 grazing cycles. Requires a high level of grass and herd management skills. Similar to high intensity-low frequency, but length of grazing and rest periods are both shorter for short-duration grazing.
High intensity-low frequency	Heavy, short duration grazing of all animals on one pasture at a time. Rotate to another pasture after forage use goal is met. Multiple pastures with single herd.	Grazing period is shorter than rest period, and grazing periods for each pasture change each year. In TX, grazing period is more than 14 days, and resting period is more than 90 days. TX typically has single herd on 4 or more pastures.
Merrill	Each of 4 pastures grazed 12 months and rested 4 months	Three herds.
Decision rotation	No specific number of herds or pastures.	No set movement pattern.

Figure 73

In all cases, however, the key management parameters are:

- Grazing frequency
- Livestock stocking rates
- Livestock distribution
- Timing and duration of each rest and grazing period
- Livestock kind and class
- Forage use allocation for livestock and wildlife

Factors to consider in determining the appropriate grazing system for any individual farm or ranch include the availability of water in each pasture, the type of livestock operation, the kind and type of forage available, the relative location of pastures, the terrain, and the number and size of different pasture units available.

Another focus of grazing management measures, beyond maximizing production efficiency, is the protection of riparian areas and the control of erosion from other grazing lands above the riparian zone (Figure 74). These measures can reduce the physical disturbance to sensitive areas and reduce the discharge of sediment, animal waste, nutrients, pathogens, and chemicals to surface waters. The loss of stream bank stability, riparian vegetation, stream habitat, and modification of the hydrologic regime due to poor grazing practices can have a devastating effect on stream life (Figure 75).

An exclusion fence installed along the edge of this pasture protects the stream and riparian areas from grazing animals.

Figure 74

Poor grazing management, as illustrated in this photo, can have devastating impacts on water quality and overall stream health.

Figure 75

Appropriate grazing management systems ensure proper grazing use by adjusting intensity and duration to reflect the availability of forage and feed designated for livestock uses, and controlling animal movement through the operating unit of grazing land. Proper grazing use will maintain enough live vegetation and litter cover to protect the soil from erosion; will achieve riparian and other resource objectives; and will maintain or improve the quality, quantity, and age distribution of desirable vegetation.

Practices that accomplish this are:

- ***Pasture and hay planting*** - establishing native or introduced forage species.
- ***Range planting*** - establishing perennial vegetation such as grasses, forbs, legumes, shrubs, and trees.
- ***Forage harvest management*** - the timely cutting and removal of forages from the field as hay, greenchop, or ensilage.
- ***Prescribed grazing*** - controlled harvesting of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective.
- ***Use exclusion*** - exclusion of animals, people, or vehicles from an area to protect, maintain, or improve the quantity and quality of the plant, animal, soil, air, water, and aesthetic resources and human health.
- ***Grazing management plan*** - a strategy designed to manage the intensity, frequency, and season of grazing to protect and/or enhance environmental values while maintaining or increasing the economic viability of the grazing operation.

It may be necessary to minimize livestock access to riparian zones, ponds or lake shores, wetlands, and streambanks to protect these areas from physical disturbance. This can be accomplished by establishing special use pastures to manage livestock in areas of concentration. Other riparian grazing management practices include exclusion fencing, animal trails and walkways through or around sensitive areas, and stabilized stream crossings.

Providing water and salt supplement facilities away from streams will help keep livestock away from streambanks and riparian zones. In some locations, artificial shade areas may be constructed to encourage use of upland sites for shading and loafing. For grazing areas with erosion problems, it may be necessary to improve or reestablish the vegetative cover on range or pastures or on streambanks. Streambank restoration efforts, exclusion fencing, stream buffer establishment, and pasture and range planting programs can significantly reduce erosion impacts due to grazing livestock.

For a sound grazing land management system to function properly and to provide for a sustained level of productivity, the following checklist should be considered:

- Know the key factors of plant species management, their growth habits, and their response to different seasons and degrees of use by various kinds and classes of livestock.
- Know the demand for, and seasons of use of, forage and browse by wildlife species.
- Know the amount of plant residue or grazing height that should be left to protect grazing land soils from wind and water erosion, provide for plant health and regrowth, and provide the riparian vegetation height desired to trap sediment or other pollutants.
- Know the range site production capabilities and the pasture suitability group capabilities so an initial stocking rate can be established.
- Establish grazing unit sizes, watering, shade (where possible) and salt locations, etc. to secure optimum livestock distribution and proper vegetation use while protecting sensitive areas.
- Provide for livestock herding, as needed, to protect sensitive areas from excessive use at critical times.

- Know the livestock diet requirements in terms of quantity and quality to ensure that there are enough grazing units to provide adequate livestock nutrition for the season and the kind and classes of animals on the farm/ranch.
- Maintain a flexible grazing system to adjust for unexpected environmentally and economically generated problems.

CORE 4 ○○○○ 4 MORE ○○●○

Principle #7: Animal Feeding Operations Management

The water quality problems associated with animal feeding operations (AFOs) result from accumulated animal wastes, facility wastewater, and storm runoff, all of which may be controlled with proper management techniques. The goal is to minimize the discharge of contaminants in facility wastewater, runoff, and seepage to ground water, while at the same time preventing any other negative environmental impacts such as increased air pollution.

Accumulated animal wastes include manure, litter, or other waste products that are deposited within the confinement area and are periodically removed by scraping, flushing, or other means and can be conveyed to a storage or treatment facility. Facility wastewater is water generated in the operation of an animal facility as a result of animal or poultry watering; washing, cleaning, or flushing pens, barns, manure pits, and other facilities; washing or spray cooling of animals; and dust control. Animal lot runoff includes any precipitation (rain or snow) that comes into contact with manure, feed, litter, or bedding and may potentially leave the facility either by overland flow or by infiltration.

Animal feeding operations have the potential to contribute large pollutant loads to waterways. Because they may be located near streams and water supplies, animal feeding operations require well planned and maintained systems of practices to minimize human health and aquatic ecosystem impacts (Figure 76).

Confined animal feeding operations create many management challenges, including on-site animal waste accumulation. This farm stores its wastewater in a surface lagoon.

Figure 76

The concentration of livestock production and housing in large systems has resulted in large accumulations of animal wastes with the potential to contribute nutrients, suspended solids, pathogens, oxygen-demanding materials, and heavy metals to surface and ground waters (Figure 77).

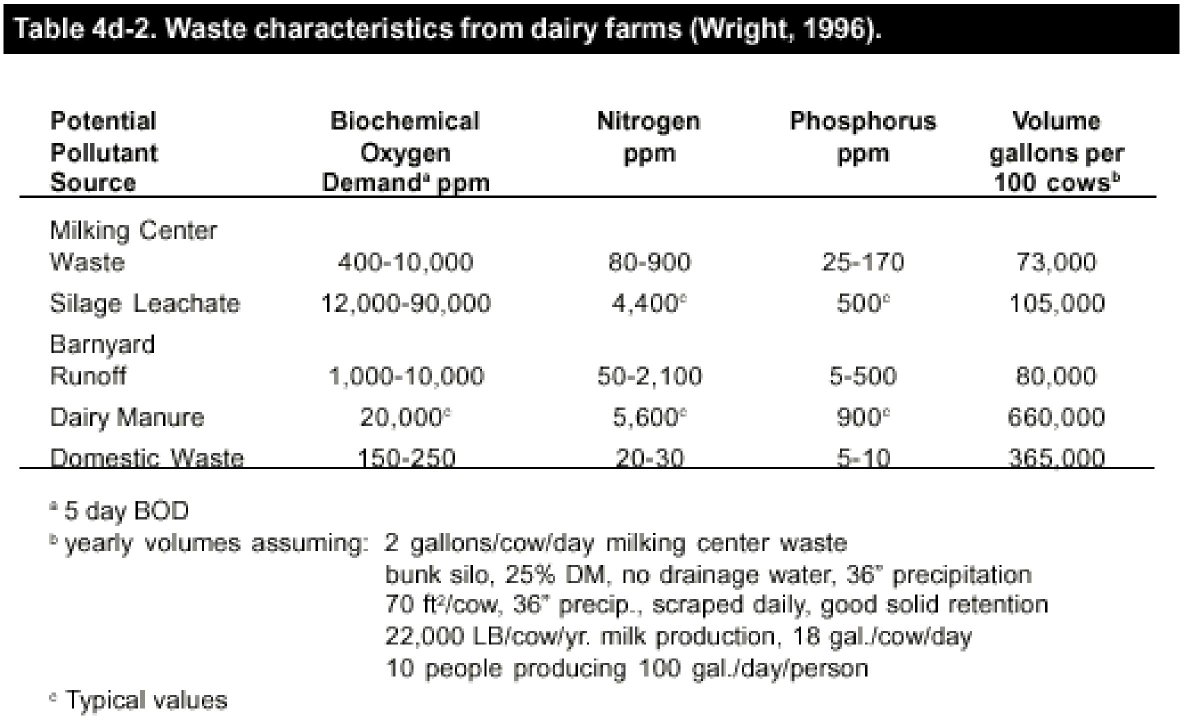


Table 4d-2. Waste characteristics from dairy farms (Wright, 1996).

Potential Pollutant Source	Biochemical Oxygen Demand[a] ppm	Nitrogen ppm	Phosphorus ppm	Volume gallons per 100 cows[b]
Milking Center Waste	400-10,000	80-900	25-170	73,000
Silage Leachate	12,000-90,000	4,400[c]	500[c]	105,000
Barnyard Runoff	1,000-10,000	50-2,100	5-500	80,000
Dairy Manure	20,000[c]	5,600[c]	900[c]	660,000
Domestic Waste	150-250	20-30	5-10	365,000

[a] 5 day BOD
[b] yearly volumes assuming: 2 gallons/cow/day milking center waste
bunk silo, 25% DM, no drainage water, 36" precipitation
70 ft²/cow, 36" precip., scraped daily, good solid retention
22,000 LB/cow/yr. milk production, 18 gal./cow/day
10 people producing 100 gal./day/person
[c] Typical values

Figure 77

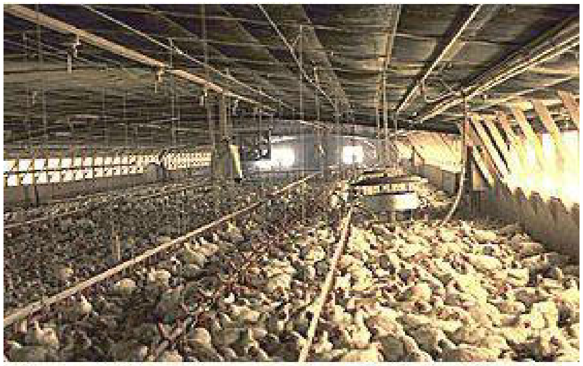
The pollution potential of such accumulation is influenced by the number and type of animals in the operation, the facilities and practices used to collect and store the wastes, and the methods chosen to manage the wastes (e.g., application to the land).

The volume of runoff from animal facilities is influenced by several major factors including water inputs (rainfall, snowmelt, and runoff entering from outside the facility) and runoff generation from impervious surfaces such as roofs and paved areas. While precipitation inputs cannot usually be managed, the diversion of clean water from upslope areas and roof runoff from the animal lot and waste storage structure (e.g. installing roof gutters on facility buildings) can reduce waste volume and storage requirements. The pollutant load carried in runoff from animal facilities is affected by several additional factors, including:

1. pollutants available for transport in the facility;
2. the rate and path of runoff movement through the facility; and
3. passage of runoff through settling or filtering practices before exiting the facility.

Management activities like scraping manure from pavement areas or proper storage of feeds and bedding can significantly reduce the availability of pollutants for transport. Structures such as detention basins can affect pollutant transport by regulating runoff movement and increasing settling within the facility.

Vegetated filter strips, riparian buffers, or other vegetated areas located around animal facilities can reduce delivery of pollutants to surface waters by infiltrating, settling, trapping, or transforming nutrients, sediment, and pathogens in runoff leaving the facility (Figures 78 and 79 identify AFOs using BMPs to reduce pollution).



Some AFO systems, such as turkey and chicken operations, can collect and store animal waste as a solid litter mixture or manure pack and eventually apply it to the land as fertilizer.

Figure 78

Dairy farms are another type of AFO utilizing best management practices to improve production and protect the environment.

Figure 79

One of the most important considerations in preventing water pollution from AFOs is the location of the facility. For new facilities and expansions to existing facilities, consideration should be given to siting the facility:

- Away from surface waters
- Away from areas with high leaching potential
- Away from critical or sensitive areas
- In areas that minimize odor drift to homes, churches, and communities
- In areas where adequate land is available to apply animal wastes in accordance with the nutrient management measure

In addition to properly siting the facility, other measures can be utilized to successfully minimize impacts. These measures are grouped into the following four AFO management categories. Specific management options for each measure are listed on the following pages. For design and implementation information, see USDA guidance manuals or visit your local agricultural extension office.

1. Practices to Divert Clean Water,
2. Practices for Waste Storage,
3. Practices for Waste Management, and
4. Practices for Mortality Management

1. Practices to Divert Clean Water

- *Diversions* - a channel constructed across the slope with a supporting ridge on the lower side.
- *Field Border* - a strip of perennial vegetation established at the edge of a field by planting or by converting it from trees to herbaceous vegetation or shrubs.
- *Field Strip* - a strip or area of vegetation for removing sediment, organic matter, and other contaminants from runoff and wastewater.
- *Grassed Waterway* - a natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff.
- *Lined Waterway or Outlet* - a waterway or outlet having an erosion-resistant lining of concrete, stone, or other permanent material.
- *Roof Runoff Management* - a facility for controlling and disposing of runoff water from roofs.
- *Terrace* - an earthen embankment, a channel, or combination ridge and channel constructed across the slope.

2. Practices for Waste Storage

- *Dikes* - an embankment constructed of earth or other suitable materials that is engineered to protect land against overflow or to regulate water.
- *Sediment Basin* - a basin constructed by a professional engineer to collect and store debris or sediment.
- *Waste Storage Facility* - an engineered structure that consists of a waste impoundment made by constructing an embankment and/or excavating a pit or dugout, or by fabricating a structure.
- *Waste Treatment Lagoon* - an engineered impoundment made by excavation or earth fill for biological treatment of animal or other agricultural wastes.

3. Practices for Waste Management

- *Constructed Wetlands* - a wetland that has been constructed for the primary purpose of water quality improvement.
- *Heavy Use Area Protection* - protecting heavy use areas by establishing vegetative cover, by surfacing with suitable materials, or by installing needed structures.
- *Waste Utilization* - using agricultural wastes or other wastes on land in an environmentally acceptable manner while maintaining or improving soil and plant resources.
- *Composting Facility* - a facility for the biological stabilization of waste organic material.
- *Application of Manure and/or Runoff Water to Agricultural Land* - manure and runoff water are applied to agricultural lands and incorporated into the soil in accordance with the nutrient management measure

4. Practices for Mortality Management

- *Composting* dead animals in a facility for the biological stabilization of waste organic matter is one of the most common methods of disposing of dead animals.
- *Rendering* is the process of transforming dead animals into useful commodities such as meat, bone meal, or fertilizer. Rendering is typically done by large regional facilities that collect the dead animals for a fee. However, the number of rendering firms has declined dramatically in recent years, and this decrease is likely to continue because the cost is high for collecting an economically feasible quantity and quality of carcasses.
- *Incinerators* have also been used as a means of disposing dead animals, particularly by producers not serviced by a renderer. Many producers using incinerators still encounter problems due to low efficiency and high fuel costs.
- *Burial of dead animals* has been a common method of disposal permitted in some states. Because of potential water quality degradation from leaching and predator concerns, however, many states reject burial as a disposal method.

Very little research has been conducted to compare the potential value, safety, and environmental threat of these disposal methods. State laws for dead animal disposal have generally been enacted based on practical experiences or theoretical assumptions. Please check with state guidelines to determine the disposal method(s) permitted in your state.

CORE 4 ○○○○ 4 MORE ○○○●

Principle #8: Erosion and Sediment Control

It is not possible to completely prevent all erosion, but erosion can be reduced to tolerable rates through proper management. In general terms, tolerable soil loss is the maximum rate of soil erosion that will permit indefinite maintenance of soil productivity (i.e., erosion less than or equal to the rate of soil development). Sedimentation causes widespread damage to our waterways. Water supplies and wildlife resources can be lost, lakes and reservoirs can be filled in, and streambeds can be blanketed with soil lost from cropland (Figure 80).

Without proper erosion and sedimentation control, soils can be lost from croplands and reduce future productivity. Soils carried from fields in runoff can also degrade streams and other receiving waters.

Figure 80

Management measures can be implemented by using one of two general strategies, or a combination of both. The first, and most desirable, strategy is to implement practices on the field to minimize soil detachment, erosion, and transport of sediment from the field. Effective practices include those that maintain crop residue or vegetative cover; improve soil properties; reduce slope length, steepness, or unsheltered distance; and reduce effective water and/or wind velocities. The second strategy is to route field runoff through practices that filter, trap, or settle soil particles. Examples of effective management strategies include vegetated filter strips, field borders, sediment retention ponds, and terraces. Site conditions will dictate the appropriate combinations for any given situation.

Wind and water erosion can combine to remove tons of soil from a field each year.

Figure 81

For both water and wind erosion, the first objective is to keep soil on the field (Figure 81). The easiest and often most effective strategy to accomplish this is to reduce soil detachment. Detachment occurs when water splashes onto the soil surface and dislodges soil particles, or when wind reaches sufficient velocity to dislodge soil particles on the surface. Crop residues (e.g. straw) or living vegetative cover (e.g. grasses) on the soil surface protect against detachment by intercepting and or dissipating the energy of falling raindrops. A layer of plant material also creates a thick layer of still air next to the soil to buffer against wind erosion. Keeping sufficient cover on the soil is therefore a key erosion control practice.

The implementation of practices such as conservation tillage (see Part One: Core 4 Priniple #1) also preserves or increases organic matter and soil structure, resulting in improved water infiltration and surface stability. In addition, creation of a rough soil surface through practices such as surface roughening will break the force of raindrops and trap water, reducing runoff velocity and erosive forces. Reducing effective wind velocities through increased surface roughness or the use of barriers or changes in field topography will reduce the potential of wind to detach soil particles. Some common examples of practices used to reduce soil detachment are:

- Conservation cover and tillage practices
- Cover and green manure crops
- Critical area planting
- Crop residue use or mulching
- Wind break/shelterbelt establishment
- Irrigation water management
- Grazing management

If soil does become detached by wind or water, the transport of sediment within the field can be reduced with the use of crop residues and vegetative cover. Other methods to reduce sediment transport within the field include terraces and diversions. Runoff can be slowed or even stopped by placing furrows perpendicular to the slope, through practices such as contour farming that act as collection basins to slow runoff and settle sediment particles. Practices are also typically needed to trap sediment leaving the field before it reaches a wetland or riparian area. Deposition of sediment is achieved by practices that slow water velocities or increase infiltration, including sediment basins, field borders, and filter strips.

Properly functioning natural wetlands and riparian areas can significantly reduce nonpoint source pollution. Loss of these systems allows a more direct contribution of nonpoint source pollutants to receiving waters (Figure 82). Therefore, natural wetlands and riparian areas should be protected and should not be used as designed erosion control practices. There pollution control functions are most effective as part of an integrated land management system focusing on nutrient, sediment, and erosion control practices applied to upland areas.

Poor sedimentation and erosion control resulted in a highly degraded waterway. This stream has badly eroded banks and deep deposits of mucky fine sediment.

Figure 82

For additional guidance, the United States Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS) or the local Soil and Water Conservation District (SWCD) can assist with planning and application of erosion control practices. Two useful references are the ***USDA-NRCS Field Office Technical Guide (FOTG)*** and the textbook entitled ***Soil and Water Conservation Engineering (Schwab et.al., 1993)***.

Summary

In this module you have received a brief introduction to eight major categories of agricultural management practices that can help protect water quality and natural plant and animal communities in agricultural areas, when used in varying combinations where appropriate as part of an overall farm management system. Four (Figure 83) are the **CORE 4** program's recommended practices. **CORE 4** is an agricultural outreach program developed by the Conservation Technology Information Center (CTIC) with support from USDA Natural Resources Conservation Service (NRCS) and the US Environmental Protection Agency (USEPA).

Summary: CORE 4 agricultural management practices . . . .

1. Conservation tillage
2. Crop nutrient management
3. Pest management
4. Conservation buffers

Figure 83

A second group of four (Figure 84) are also essential for watershed health in many agricultural settings. These practices were adapted from the US EPA's ***National Management Measures to Control Nonpoint Source Pollution***, specifically from the agricultural management measures. These measures are widely applicable throughout US agricultural lands to protect water quality, fish, and wildlife. They are general guidelines that are updated and reviewed by the public every few years.

. . . . and 4 more agricultural management practices . . . .

5. Irrigation water management
6. Grazing management
7. Animal feeding operations management
8. Erosion and sediment control

Figure 84

Good stewardship of agricultural land can make a significant difference in America's waters and all the benefits we gain from them. Agriculture and water bodies are very often located nearby one another, but pollution, erosion and soil loss needn't be part of the picture. The eight practices discussed in this module are common agricultural methods. Using these practices can save soil, save money, and protect the health of US waters as a valuable part of our agricultural landscapes.

Acknowledgments

We thank CTIC and USDA/NRCS for their cooperation in the use of CORE 4 visuals throughout much of this module. Thanks also to Doug Gahn (USDA/NRCS), Sharon Buck, Paul Thomas, Tom Davenport, Joan Warren, Beverly Ethridge (all of EPA), and Vicki Watson (U of Montana) for technical review.

Self Test for Agriculture Management Practices for Water Quality Protection

After you've completed the quiz, check your answers with the ones provided on page 54 of this document. A passing grade is 14 of 20 correct, or 70 percent.

Core 4

1. Conservation tillage techniques leave all or a portion of the previous crop's residue on the soil surface. This residue can provide which benefit(s) to soil quality:

☐ A. Increased infiltration
☐ B. Reduction in the splash effect of rainfall
☐ C. Reduced surface runoff
☐ D. All the above

2. The major economic factor(s) that may cause producers to consider conservation tillage systems, such as no-till, include:

☐ A. Reduced labor costs
☐ B. Equipment savings
☐ C. A and B
☐ D. Neither A or B

3. Which conservation tillage technique retains the most surface residue cover, potentially reducing sheet and rill erosion by 94 percent or more:

☐ A. Ridge-till
☐ B. No-till/strip-till
☐ C. Mulch-till
☐ D. Terracing

4. Which of the following is not a major function of crop nutrient management:

☐ A. Increasing fertilization rates to produce bigger fruits and vegetables
☐ B. Maintaining and improving the physical, chemical, and biological condition of the soil
☐ C. Providing efficient and effective use of nutrient resources
☐ D. Minimizing environmental degradation caused by excessive nutrient inputs to the environment

5. Excessive amounts of nutrients used in agricultural production can cause an imbalance in the environment. Negative impacts can include:

☐ A. Impaired use of waterbodies due to proliferation of aquatic plants
☐ B. Unsafe drinking water risks to humans and animals
☐ C. Air quality problems, including greenhouse gases and offensive odors
☐ D. All the above

6. Which of the following agronomic assessment tools help the nutrient management planner effectively determine the amount and type of nutrients required:

☐ A. Soil tests
☐ B. Plant tests
☐ C. Irrigation water tests
☐ D. All the above

7. Integrated pest management (IPM) is a pest control approach based on which of the following goals:

☐ A. Maximizing use of naturally occurring pest control measures, such as pest disease, predation, and parasites
☐ B. Eliminating the use of all chemical pesticides
☐ C. A and B
☐ D. Neither A or B

8. Which of the following is not one of the five common sense principles of integrated pest management (IPM):

☐ A. Tolerate, don't eradicate
☐ B. Increase pesticide levels to combat resistance
☐ C. Treat the causes of pest outbreaks, not the symptoms
☐ D. If you kill the natural enemies of pests, you inherit their job

9. Which of the following is an example of a conservation buffer:

☐ A. Herbaceous wind barrier
☐ B. Vegetative filter strip
☐ C. A and B
☐ D. Neither A or B

10. A riparian forest buffer is an area of trees and shrubs located adjacent to a waterbody. Benefits of these types of conservation buffers can include:

☐ A. Interception of sediment, nutrients, and pesticides
☐ B. Habitat for wildlife
☐ C. Streambank protection
☐ D. All the above

4 more

11. Select the best example of a pressure-based system of irrigation from the following:

☐ A. Canals and ditches
☐ B. Level basins
☐ C. Sprinklers
☐ D. Subsurface drains

12. Effective irrigation management provides enough water to meet the needs of the crop. Other goals can include:

☐ A. Limiting erosion from applied water
☐ B. Reducing the movement of pollutants from land into ground or surface waters
☐ C. Minimizing wasted time, energy, and water
☐ D. All the above

13. Which of the following aspects of irrigation systems is not considered as part of an effective irrigation management plan:

☐ A. Flood control
☐ B. Irrigation scheduling
☐ C. Transport of irrigation water
☐ D. Use of runoff or tailwater

14. Range refers to lands such as:

☐ A. Pastures
☐ B. Natural grasslands
☐ C. Croplands used to produce animal feed
☐ D. All the above

15. There are a variety of grazing systems that managers may select from. In all cases, the key management parameter(s) include:

☐ A. Grazing frequency
☐ B. Livestock stocking rates
☐ C. Livestock distribution
☐ D. All the above

16. Grazing management measures are also aimed at protecting waterbodies and riparian areas. Techniques to achieve these goals include:

☐ A. Exclusion fencing
☐ B. Stabilized stream crossings
☐ C. A and B
☐ D. Neither A or B

17. Which of the following is not a management challenge associated with animal feeding operations:

☐ A. Proper handling of animal wastes
☐ B. Prescribed grazing
☐ C. Storage and treatment of facility wastewater
☐ D. Animal lot runoff

18. In addition to properly siting an animal feeding operation, there are other management measures essential to minimizing environmental impacts such as:

☐ A. Practices to divert clean water
☐ B. Practices for mortality management
☐ C. A and B
☐ D. Neither A or B

19. The most effective erosion control strategies include those that maintain vegetative cover to minimize soil detachment from wind and water:

☐ A. True
☐ B. False

20. Sedimentation can cause widespread damage to waterways. Effective management strategies aimed at reducing sedimentation impacts include:

☐ A. Field borders

☐ B. Vegetated filter strips

☐ C. Sediment retention ponds

☐ D. All the above

Answers for Agriculture Management Practices for Water Quality Protection Module Self Test

Q1: D Q2: C Q3: B Q4: A Q5: D Q6: D Q7: A Q8: B
Q9: C Q10: D Q11: C Q12: D Q13: A Q14: B Q15: D Q16: C
Q17: B Q18: C Q19: A Q20: D