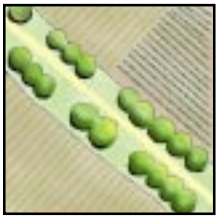
Conservation Buffers

Planning and Design Principles



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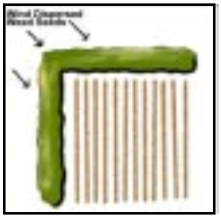

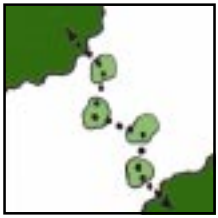

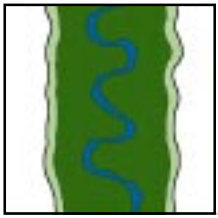

USDA NATIONAL AGROFORESTRY CENTER

BACKGROUND

This publication is part of a comprehensive, interdisciplinary effort to develop a scientific basis for planning and designing conservation buffers. Funding for this effort was provided through the USDA National Agroforestry Center, which is part of the U.S. Forest Service Rocky Mountain Research Station, and the University of Missouri Center for Agroforestry under cooperative agreements AG-02100251 with the Agricultural Research Service (ARS) and CR 826704-01-0 with the US Environmental Protection Agency (EPA).

DRAFT VERSION-Fall 2004

This draft version was prepared to test and evaluate the utility of illustrated principles in actual buffer planning and design projects. The objective of field testing a draft manual is to ensure that the final product will satisfy the needs of resource planners and managers.

Although the principles in this guide were synthesized from research, this draft version has not yet been reviewed by resource experts. During the field testing phase, this guide will be peer reviewed by experts to ensure the scientific validity of the principles.

Since this is a draft version, it should not be cited or referenced till the formal reviews are completed and the final document is prepared.

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ACKNOWLEDGMENTS

The authors of this guide would like to thank the many scientists, engineers, and planners whose research is synthesized in this manual. Their research provides a solid foundation for planning and designing conservation buffers that can satisfy community and landowner goals.

Specifically, the authors would like to extend their sincere appreciation to the Agricultural Research Service and the Environmental Protection Agency for their funding and support in developing this guide. The U.S Forest Service and Natural Resources Conservation Service provided funds for printing this guide.

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Although the principles in this guide were synthesized from research, this draft version has not yet been reviewed by experts in the various disciplines. During the field testing phase, this guide will be thoroughly reviewed by experts to ensure the scientific validity of the principles.

As a user of this manual, we would greatly appreciate your suggestions and comments on this guide to assist us in preparing a final version. Please contact Gary Bentrup at the USDA National Agroforestry Center to provide feedback. Your input will be sincerely appreciated.

USDA National Agroforestry Center
East Campus-UNL
Lincoln, NE 68583-0822
(402) 437-5178 ext. 18
gbentrup@fs.fed.us

FOREWORD

Many of the professionals working in agroecosystems were often trained in one natural resource discipline and may feel uncomfortable making design recommendations that cross into other resource disciplines. Consequently, our conservation practices and particularly buffer designs are often developed for only one resource issue.

There is a great need to design and implement buffer systems that can solve several resource concerns. Not only will this ensure appropriate use and protection of natural resources, it will also support greater public acceptance and adoption of buffers in appropriate locations.

This manual serves a valuable role by providing planners and managers the information necessary to make design recommendations for buffers to address several resource issues.....

(Final foreword to be prepared by an outside reviewer).

INTRODUCTION

Conservation buffers or linear strips of vegetation that modify ecological processes, are prominent landscape features in many agroecosystems in the United States. Examples of conservation buffers, both natural and human-created, include windbreaks, grassed waterways, riparian corridors, filter strips, and greenways (Fig. 1).

Protecting soil resources, improving air and water quality, enhancing fish and wildlife habitat, and beautifying the landscape are some of the main benefits of conservation buffers. In addition, buffers can offer landowners opportunities for economic diversification including protection and enhancement of existing enterprises.

Well-designed and managed buffers can address a variety of ecological, social, and economic issues simultaneously. The challenge is to integrate these issues into a comprehensive, multipurpose buffer plan based on sound scientific principles.

Research on natural resources and social sciences has yielded a vast storehouse of information useful for buffer planning and design. Unfortunately, this information is sequestered in scientific journals, books, and proceedings, not easily accessible for most resource planners and designers.[71] The authors' primary goal was to review and synthesize this diverse scientific and engineering knowledge and to distill this information into easy-to-understand planning and design principles.[118, 180] This approach to synthesizing and distributing research knowledge has been used successfully in several publications.[39, 46, 47, 76]

Fig. 1: *Conservation buffers in an agroecosystem.*

Fig. 2: *Illustrated planning and design principles for conservation buffers.*

Over 80 planning and design concepts are presented in this guide gleaned from a diffused body of research and literature (Fig. 2). Information was synthesized from landscape ecology, conservation biology, agricultural engineering, agronomy, economics, social sciences, hydrology, landscape perception, and other disciplines. These principles can serve as a basis for designing new buffers and for managing existing ones. Each principle or guideline is referenced by footnote numbers, linking the principle with the literature it was based upon. In this way, the manual also serves as an introduction to the diverse literature base on buffers.

Several caveats need to be mentioned regarding this guide. First, there are still many information gaps in our understanding of buffers and their ecological and socioeconomic functions. Some of the principles in the guide reflect many years of research and offer a high level confidence while other principles are based on limited research and reflect a higher level of intuition. The guide should not serve as a substitute for using an interdisciplinary team approach to design. In addition, other design and engineering manuals and standards should be used when appropriate.

Second, this guide is not a cookbook for resource planning. The planner is still required to carefully weave these principles together to yield a comprehensive plan that optimizes benefits and mitigates potential problems.

Although this field guide was written for agroecosystems in the U.S., many aspects of this manual will be transferable to other ecosystems including urban and suburban areas. This manual is also part of a larger suite of planning and design tools for conservation buffers. Please refer to http://www.unl.edu/nac/conservation/ for more information.

BUFFERS: AN OVERVIEW

Landscape ecologists suggest that a landscape is a heterogeneous land area consisting of three fundamental elements: patches, corridors or buffers, and a matrix (Fig. 3).[46, 76]

Fig. 3: *The landscape described in basic landscape ecology terms.*

Patch: A plant and animal community that is surrounded by areas with different community structure.

Corridor or Buffer: A linear patch that differs from its surroundings. (*The term corridor and buffer will be used interchangeably in this guide*).

Matrix: The background within which patches and buffers exist.

In agroecosystems, patches are often remnant areas of woodland or prairie, buffers are linear elements like windbreaks and riparian areas, and the matrix is often cropland, pastureland, or even urban areas. All three elements are interactive components that influence the flow of energy, matter, and organisms and are continually being modified to produce goods and services.

Although this guide focuses on planning and designing for buffers, patches and matrix areas must be considered in the process to achieve the desired goals. Location, structure, and management of the nearby patches and matrix influence the types of functions the buffers will perform. In addition, patch and matrix factors will strongly determine the effectiveness of the buffers to achieve the desired functions. The landscape and its' components must be treated as a dynamic and interrelated system (Fig. 4).

Fig. 4: *The landscape is a dynamic and interconnected system.*

It is critical for designers to consider how the various landscape elements are intertwined and function as a system. For instance, appropriate management of the cropland matrix, such as conservation tillage and nutrient management, is necessary to prevent overloading of a buffer with sediment and nutrients.

Likewise, a buffer can be both a source of desirable elements like beneficial insects or undesirable elements like invasive weeds. Therefore, the flows of materiels, energy, and species must be considered holistically. In addition, these systems are highly dynamic, requiring a long-term temporal perspective. The plant communities within patches, corridors, and matrix will change over time, along with changes in ecological functioning. These changes must be planned for and managed in order to achieve the desired goals.

Types of Buffers

Buffers can be classified into five different categories based on their origin.[46, 76] It is important to understand the diversity of buffer types and the processes that have resulted in their creation.

Environmental Buffers

Environmental buffers are the result of a vegetation response to an environmental resource such as soil type, proximity to streams, or a geologic formation. They are typically meandering in configuration with widths that are highly variable.

Remnant Buffers

Remnant buffers are strips of vegetation on sites too steep, rocky, or wet to be cleared and put into production. The width and configuration of most remnant buffers varies considerably. These relics may often contain the last assemblages of native flora and fauna in the region.

Introduced Buffers

Introduced buffers are planted strips designed to achieve a particular function such as a windbreak modifying wind flow. The width and configuration of introduced corridors is often very regular and uniform.

Disturbance Buffers

Disturbance buffers are created by land management activities that disturb vegetation in a line or strip such as a mowed roadside ditch or brush-hogged powerline right-of-way. Continued disturbance often maintains the vegetation in a desired successional stage.

Regenerated Buffers

Regenerated buffers are products of regrowth in a disturbed line or strip. Regrowth may be the product of natural succession or revegetation via planting. Regrowth along abandoned right-of-ways or along fence lines are some examples.

Buffer Functions

Human interest in buffers is based upon the ability of these landscape features to address societal goals. The role buffers play in addressing these goals results from a number ecological functions that buffers can preform. Ecological function is used broadly, encompassing biophysical modifications like reducing runoff energy and social modification, including aesthetics and community cohesion. Table 1 illustrates the primary issues buffers can address and their associated ecological functions.

Table 1: *Relationship of buffer goals and ecological functions.*

ISSUE AND PRIMARY GOALS	ECOLOGICAL FUNCTIONS
Water Quality	
Reduce erosion of sediment, nutrients and other contaminants	Slow water runoff and enhance infiltration Trap and transform contaminants in surface runoff Trap and transform contaminants in subsurface runoff
Remove contaminants from water runoff and wind	Stabilize soil particles Reduce bank erosion
Species and Habitats	
Enhance aquatic habitat	Increase overall habitat area Protect sensitive habitats from negative impacts
Enhance terrestrial habitat	Restore connectivity between habitats Increase access to food, cover, and water resources Provide shade to maintain cooler stream temperatures
Stable and Productive Soils	
Reduce soil erosion Increase soil productivity	Reduce water runoff energy Reduce wind energy Stabilize soil particles Increase organic matter Increase infiltration
Economic Opportunities	
Provide alternative income sources Increase economic diversity Increase economic value	Grow marketable products Enhance habitat for marketable wildlife Increase property values Reduce energy consumption Increase crop yields
Protection and Safety	
Manage wind or snow Increase biological control of pests Protect from floodwaters	Reduce wind energy Modify microclimate Manage habitat for biological pest management Reduce erosive force of floodwaters
Aesthetics and Visual Quality	
Enhance visual quality Control noise levels Control air contaminants and odor	Create visual diversity Screen undesirable views Reduce noise Filter air contaminants and odor
Outdoor Recreation	
Promote wildlife viewing and hunting opportunities	Increase habitat area Restore connectivity between habitats Provide a conduit for pedestrian movement
Provide buffers as recreational trails	

Because buffers perform a variety of ecological functions, planners need to consider the full range of potential functions and impacts. Most buffers will perform more than one function, even if they were designed with only one function in mind. Proper design and management of a buffer depends on a clear and detailed plan of its intended functions as well as the unintended impacts that may or may not be beneficial.

One way to organize this information is a simple buffer function table that outlines the primary goals or objectives, desired functions, and potential problems.[67, 144] See Table 2. During this process, functional conflicts between objectives may be discovered, requiring the modification of initial project goals. If quantitative goals are included in the table, it can also serve as a valuable tool for monitoring the effectiveness of the buffer project.

Buffer Location

One of the most important factors influencing buffer functions is the location of the buffer in the landscape. Soils, slope position, spatial relationship with the surrounding matrix and patches are just some of the location-specific factors that will determine the types and functions of the proposed or existing buffers. In some locations, the desired buffer functions will be compatible and in other cases, they may be opposing.

For instance, buffers used for nitrate removal require permeable soils with high organic matter and soil moisture to promote denitrification while buffers used for phosphorus removal need dry soil to encourage infiltration and deposition. The challenge of designing and managing a buffer system is integrating and balancing the desired goals with the ecological functions.

Geographic information systems (GIS) can be a useful tool for identifying suitable locations for buffers. By defining and ranking the necessary landscape characteristics for the desired functions, suitable locations can be determined. The real power in using GIS is the ability to develop assessments that determine where multiple objectives and functions can be simultaneously achieved. Please refer to http://www.unl.edu/nac/conservation/ for more information on using GIS for buffer planning.

Table 2: *Example of a buffer function table for a proposed riparian buffer.*

Objective	Ecological Functions	Potential Problems
Reduce 50% of nitrogen from surface runoff.	Slow water runoff and enhance infiltration. Trap and transform contaminants in surface runoff.	Weed species may invade buffer due to nitrogen loading.
Allow movement for tiger salamanders.	Increase overall habitat area. Restore connectivity between habitats.	Selected plant species must not restrict salamander movement.
Produce woody products for the decorative floral industry.	Grow marketable plant products.	Introduced woody species for the decorative floral market should not be invasive.
Increase biological control of crop pests.	Provide and manage habitat for biological pest control.	Undesirable pest species may also benefit from the buffer habitat.
Reduce soil erosion.	Reduce water runoff energy. Stabilize soil particles.	Selected plant species should not be invasive or nitrogen-fixing for water quality concerns.
Enhance visual quality.	Create visual diversity. Screen undesirable views.	Need to ensure that desired views are not screened.

Buffer Structure

In addition to location, the physical and biological characteristics of buffers such as width, height, length, connectivity, plant community structure, and specific plant species determine how these landscape features function. These are the variables that planners and landowners can manipulate to achieve the desired goals of the buffer system. The principles in this manual address many of these design and management parameters.

Goals and Multiple Scales

Societal goals and needs along with ecological functions are the primary drivers that shape our landscapes. Community desires and concerns may differ from individual landowner goals and objectives. Sometimes the issues are compatible and other times there will be conflicting buffer functions and goals.

Too often buffers are designed at the site scale without taking in consideration the relationships of the buffer system in the larger landscape or watershed. Creating effective buffer systems with broad public support requires simultaneously addressing landowner and societal goals while paying respect to the ecological processes that cross spatial boundaries [76, 115, 126] (Fig. 5).

Fig. 5: *Multiple spatial scales need considered in the planning process.*

To accomplish this challenge, a multi-scale approach to designing and managing conservation buffers should be used. We suggest using a three-scale approach to planning for buffers (Fig. 6). At the regional scale, a reconnaissance of existing information provides a general assessment of environmental conditions and resource issues. Policy is the primary way to influence regional scale buffer design and management through incentive programs and regulations.

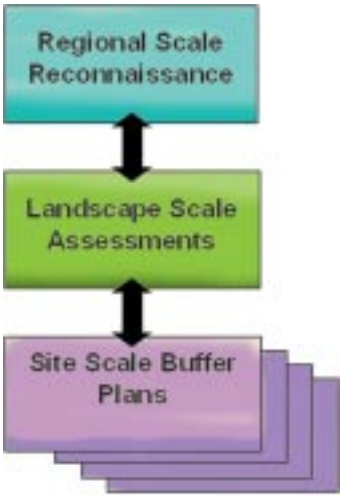


Fig 6: Three-scale planning and design process.

At the landscape or watershed scale, more detailed information is collected and analyzed to identify critical problems areas and opportunities. Assessments using GIS are valuable for determining where buffers might be appropriate to solve the collection of issues and achieve the desired future conditions.

The site scale component incorporates the information from the regional reconnaissance and landscape assessments with site specific information. Design alternatives that integrate community-desired future conditions and landowner objectives are generated for the site. Design alternatives include buffer configuration, composition, and management recommendations.

The entire process is guided by questions, which provides an efficient but flexible direction for analyzing resources and developing plans.[101, 126, 149] This approach is particularly effective at preventing issues from being inadvertently overlooked. More information on this planning process can be found at http://www.unl.edu/nac/conservation/.

Through this planning process, a comprehensive buffer system can emerge that addresses landowner and community goals while taking in consideration the opportunities and constraints imposed by the landscape characteristics. The result is system of buffers specifically designed to solve different issues across the watershed (Fig. 7). For instance, in section A-A, the buffer is designed to filter agricultural runoff through a dense native vegetative filter that also provides habitat and a conduit for wildlife.

In contrast, section B-B illustrates a buffer in a more urbanized section of the watershed. Because stormwater is concentrated, a constructed wetland is designed in the buffer system to treat the runoff before it flows into the stream. More active recreation is included, providing a firebreak to protect homes. Although wildlife may still benefit from this buffer, this objective plays a lesser role than in section A-A because of its' landscape context.

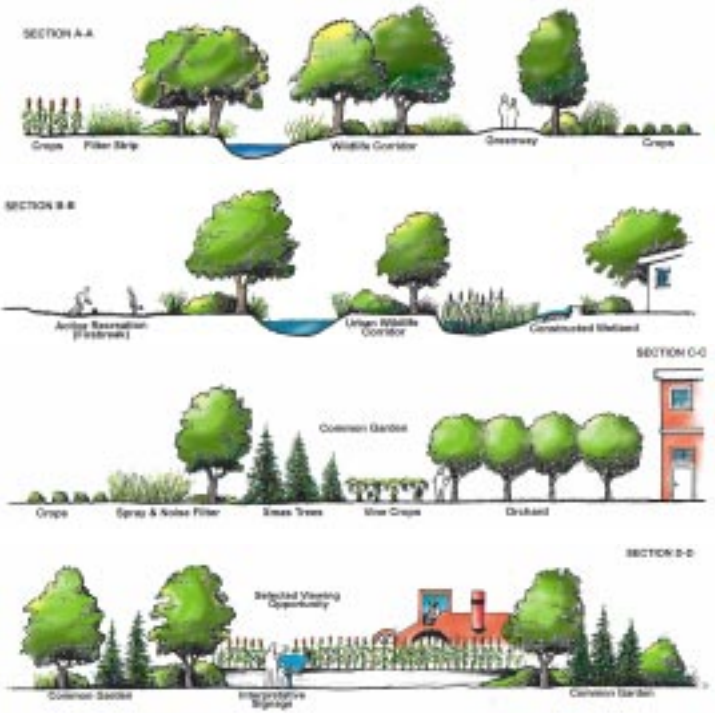
A buffer between an agricultural field and a residential area is presented in section C-C. This buffer, which serves as a common garden for both rural and urban residents, is protected from noise and spray by a vegetative barrier. Products such as fruits, nuts, Christmas trees, floral items can be harvested from the buffer. Section D-D illustrates how this same buffer can provide views between land uses at selected points. Interpretative signage has also been incorporated into the buffer to educate residents about conservation measures to protect natural resources. Although this example is purely conceptual, it demonstrates how objectives and design parameters change with location.

HOW TO USE THIS GUIDE

This guide supports the multi-scale planning and design process by offering science-based principles to help assess potential buffer sites and to develop design criteria. The principles are organized into seven resource sections:

- Water Quality
- Species and Habitats
- Stable and Productive Soils
- Economic Opportunities
- Protection and Safety
- Aesthetics and Visual Quality
- Outdoor Recreation

Fig. 7: *Conceptual buffer plan and sections demonstrating several types of conservation buffers throughout the watershed. Each buffer accomplishes different sets of functions and goals.*



As the buffer planner works with an individual landowner or watershed stakeholder group, the primary issues of concern and ecological functions can be identified and documented in a function table as demonstrated in Table 2. Using this type of table for guidance, the planner can then refer to the specific resource sections to find planning and design principles relevant to their project.

In the beginning of each of the seven resource sections, a table is provided that lists the principles and the ecological functions that the principles address (Table 3). A set of applicable principles can be developed from these tables for one's project.

For instance in our example, reduction of nitrogen in surface runoff was listed as one of our goals. The ecological functions to achieve this goal are slow water runoff and increase infiltration and trap and transform contaminants in surface runoff. By referring to the Water Quality Principle table (Table 3), we can quickly find the principles relevant to our desired ecological functions. These principles can be added to our design table and be used to guide the buffer planning and design (Table 4). This process is then repeated with the other goals and ecological functions.

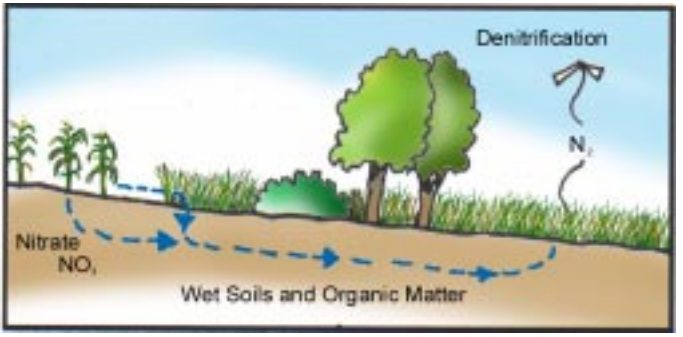
Table 3: A portion of the Water Quality Principle table.

Water Quality Principles	Slow water runoff and enhance infiltration	Trap and transform surface runoff	Trap and transform subsubsurfcae flow	Stabilize soil particles	Reduce bank erosion
1.1 Filter vegetation should be non-dormant during runoff season.	■	■		■	
1.2 Groundwater flow must be in root zone.			■		
1.3 Constructed wetlands for tile drainage.		■			
1.4 Promoting denitrification.		■	■		
1.5 Phosphorus storage in upland buffers.		■			
1.6 Biomass removal.		■	■		

Table 4: *Example of the function table with a list of applicable planning and design principles.*

Objective	Ecological Functions	Potential Principles
Reduce 50% of nitrogen from surface runoff.	Slow water runoff and enhance infiltration. Trap and transform contaminants in surface runoff.	1.1, 1.3, 1.4, 1.6, 1.9, 1.10, 1.11, 1.12, 1.14
Allow movement for tiger salamanders.	Increase overall habitat area. Restore connectivity between habitats.	2.12, 2.14, 2.15, 2.20, 2.22, 2.26
Produce woody products for the decorative floral industry.	Grow marketable plant products.	4.1, 4.2, 4.3
Increase biological control of crop pests.	Provide and manage habitat for biological pest control.	5.2, 5.3, 5.5
Reduce soil erosion.	Reduce water runoff energy. Stabilize soil particles.	3.1, 3.4, 3.5, 3.6, 3.7, 1.1, 1.9, 1.12, 1.13, 1.15
Enhance visual quality.	Create visual diversity. Screen undesirable views.	6.1, 6.2, 6.4, 6.6, 6.8

Figure 8 illustrates one of the design principles. Text and a diagram are used to demonstrate the principle in an easy-to-understand format. At the end of the description, footnote numbers are provided which link the principle to the literature it was based upon in the Reference section of this guide.



1.4 Promoting Denitrification

For control of nitrate, buffer zone soils should be wet or hydric and should have high organic matter content to encourage denitrification. Ideally, soils should have moderate to high permeability to encourage passage of nitrate-containing water through the soils. The challenge is finding these soils with somewhat opposing characteristics. [3, 24, 35, 56]

Footnote numbers for the reference section.

Fig. 8: *An example of a illustrated design principle.*

It should be noted that this guide does not provide a step-by-step process for planning and designing buffers but instead offers key concepts that should be considered during the design process. When the principles are coupled with other design and engineering standards, a solid, science-based buffer design can be created.

Figures 9 and 10 demonstrate how to use the principles with aerial photos. The Case Study section of the guide offers short examples where several of the buffer design principles were applied and the Glossary provides definitions for key terms .

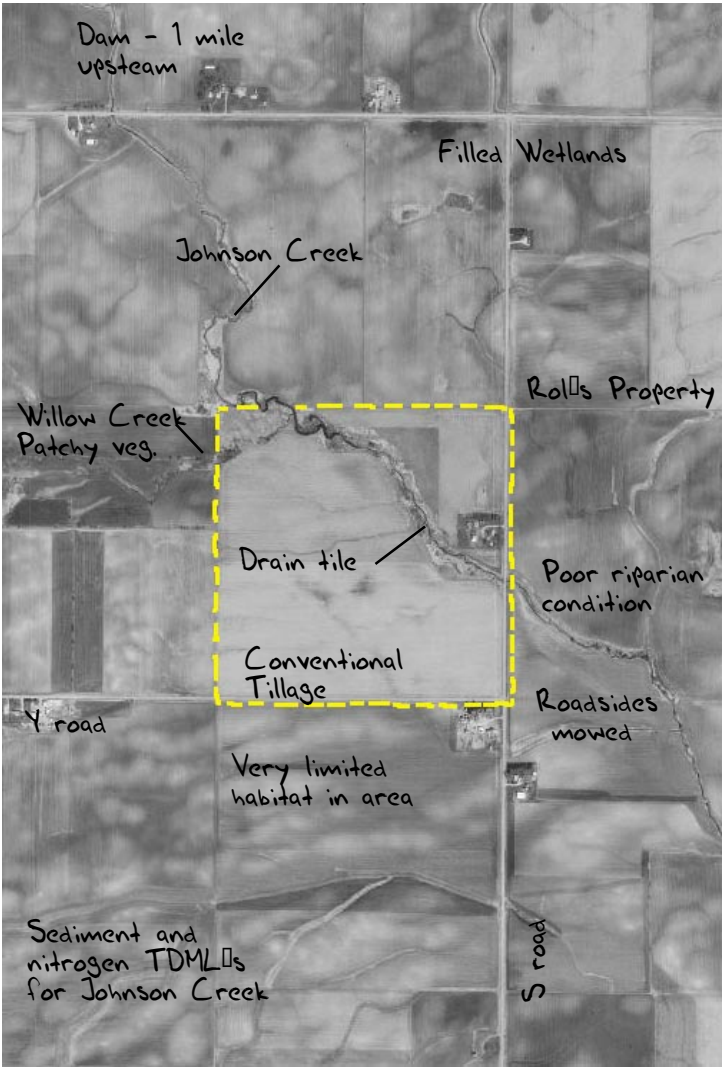


Fig. 9: *Example of an area map with basic inventory data.*

Figure 9 illustrates the importance of considering the site within the larger landscape context. Aerial photos can be invaluable for recording observations that will be used in the design process. Using photocopies of the photos, notes can be made in color pencils or markers. The next page demonstrates a site plan on an aerial photo.

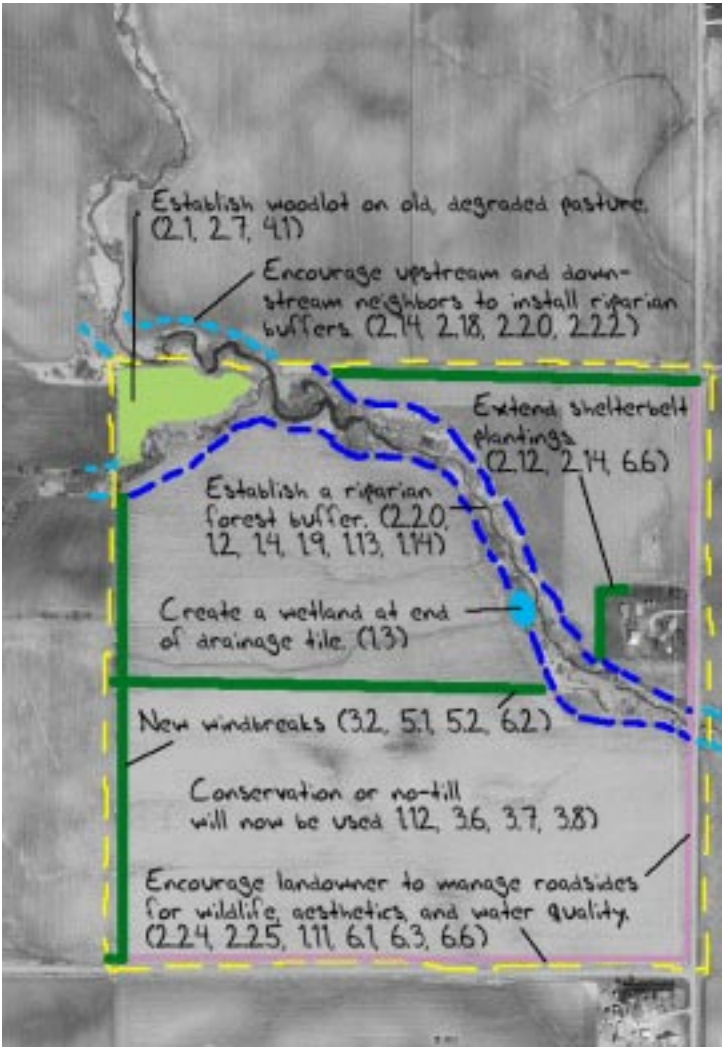


***Fig.10**: Example of a concept site plan with applicable planning principles.*

Figure 10 illustrates a concept plan based upon community and landowner goals. The conservation measures were developed using the principles in this manual. The numbers listed by the proposed actions reference the specific principles, allowing easy tracking of the design process.

WATER QUALITY

- *Reduce erosion of sediment, nutrients, and other potential contaminants*
- *Remove contaminants from water runoff and wind*

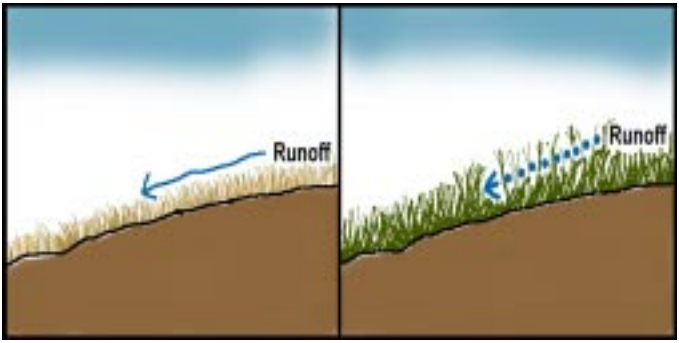
Potential Buffer Impacts on Ecological Function:

1. Slow water runoff and enhance infiltration
2. Trap and transform contaminants in surface runoff
3. Trap and transform contaminants in subsurface flow
4. Stabilize soil particles
5. Reduce bank erosion

Water Quality Principles	Slow water runoff and enhance infiltration	Trap and transform surface runoff	Trap and transform subsurface flow	Stabilize soil particles	Reduce bank erosion
1.1 Non-dormant filter vegetation.	■	■		■	
1.2 Groundwater flow in the root zone.			■		
1.3 Constructed wetlands for tile drainage.		■			
1.4 Promoting denitrification.		■	■		
1.5 Phosphorus storage in upland buffers.		■			
1.6 Biomass removal.		■	■		
1.7 Incised channels and nitrate removal.			■		
1.8 Seeps and groundwater nitrate removal.			■		
1.9 Sediment trapping and soil properties.	■	■			
1.10 Species change from pollutant loading.		■			
1.11 Roadsides for water quality.	■	■		■	

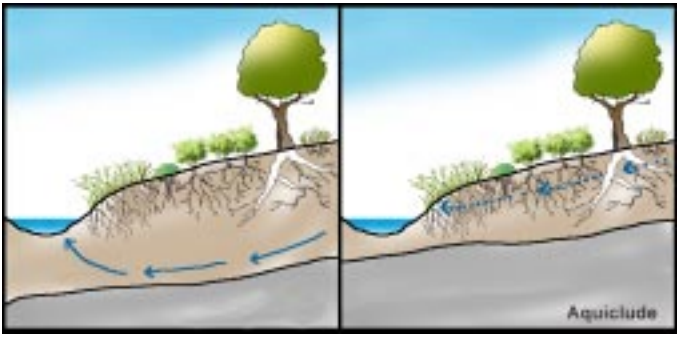
Water Quality Principles	Slow water runoff and enhance infiltration	Trap and transform surface runoff	Trap and transform subsurface flow	Stabilize soil particles	Reduce bank erosion
1.12 Buffers and field management.	■			■	
1.13 Roots and streambanks.				■	■
1.14 Watershed location of buffers.	■	■			
1.15 Flood reduction and sediment control.	■	■		■	■
1.16 Waterbreaks	■	■		■	■
1.17 Determining buffer widths for filtering agricultural runoff.	■	■			

Other Principles Related to Water Quality	Slow water runoff and enhance infiltration	Trap and transform surface runoff	Trap and transform subsurface flow	Stabilize soil particles	Reduce bank erosion
2.19 Wider corridors are better than narrow corridors.	■	■	■		
2.21 Continuous stream corridors.	■	■	■	■	■
3.1 Conveyance zones and sediment.	■	■			
3.3 Buffers and infiltration.	■	■			
3.4 Water Erosion Prediction Project.	■	■			
3.5 Residue management: buffers.	■	■		■	
3.6 Residue management: erosion.	■	■		■	



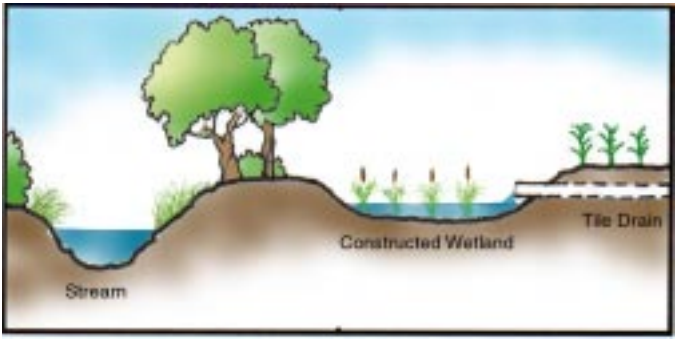
1.1 Non-Dormant Filter Vegetation

Vegetation selected for filtering surface runoff should be actively growing during the dominant runoff season. This ensures the highest filtration and greatest nutrient uptake. For instance, cool season grasses may be better than warm season grasses for early spring runoff events.[120, 125]



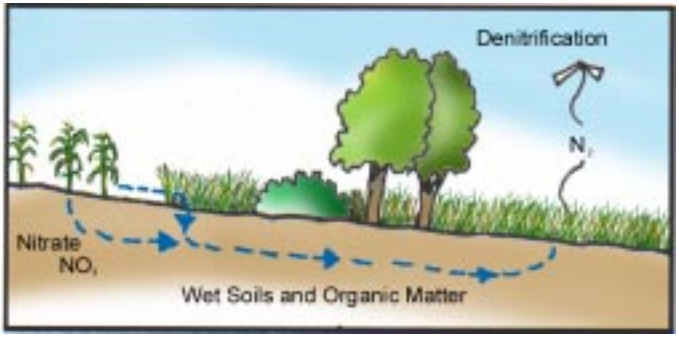
1.2 Groundwater Flow in the Root Zone

To filter pollutants in shallow groundwater, subsurface flow needs to be moving through the root zone of the buffer. Even if flow is occurring through the root zone, the volume treated may not be significant unless there is a shallow confining layer or aquiclude constraining the flow through the root zone.[52, 75, 88, 177]



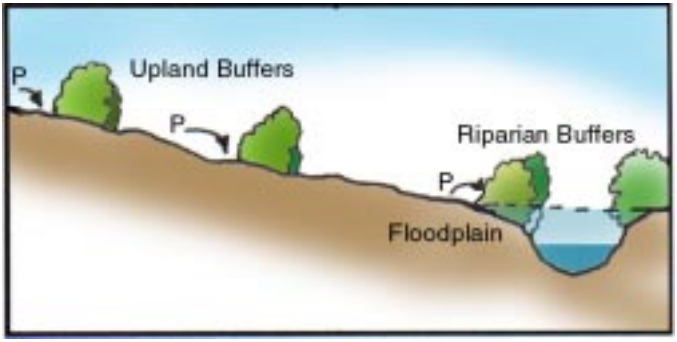
1.3 Constructed Wetlands for Tile Drainage

Wetlands constructed at the outlet of tile drains can filter, trap, and transform pollutants before being released into a lake or stream. To provide effective removal of most contaminants, water should take 10-15 days to flow through the wetland. Wetlands should generally be sized at 2-4 percent of the contributing watershed area.[47, 120, 123]



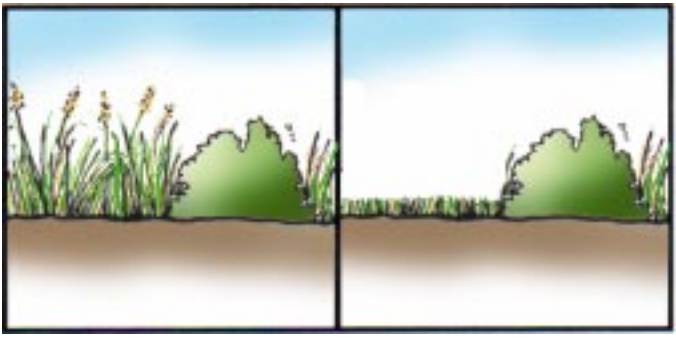
1.4 Promoting Denitrification

For control of nitrate, buffer zone soils should be wet or hydric and should have high organic matter content to encourage denitrification. Ideally, soils should have moderate to high permeability to encourage passage of nitrate-containing water through the soils. The challenge is finding these soils with somewhat opposing characteristics.[52, 62, 88, 120, 125, 143, 171]



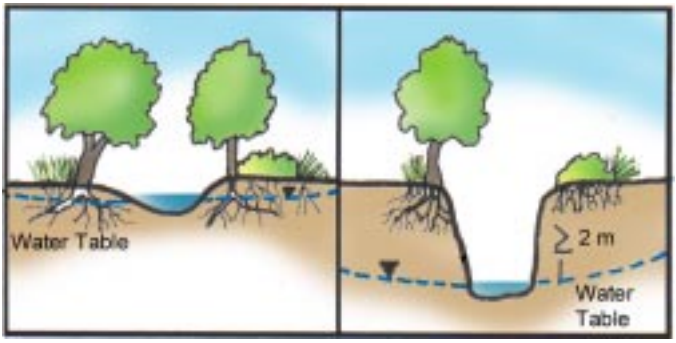
1.5 Phosphorus Storage in Upland Buffers

Phosphorus should generally be trapped in upland buffers and not riparian buffers. Phosphorus stored in riparian buffers will be susceptible to being flushed out with flood waters.[34, 62, 107, 152, 171]



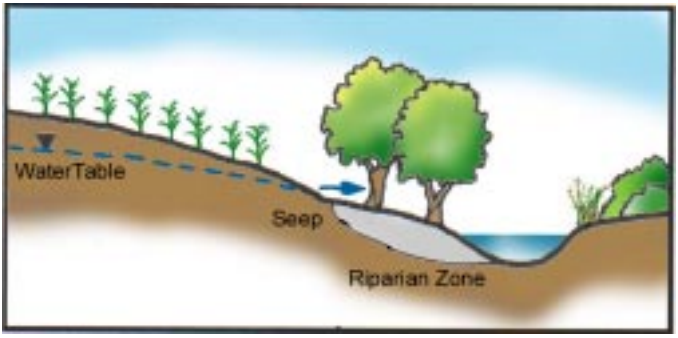
1.6 Biomass Removal

It maybe necessary to harvest and remove the herbaceous component of the buffer in order to encourage vigorous plant growth and to continue nutrient uptake. [62, 142, 171]



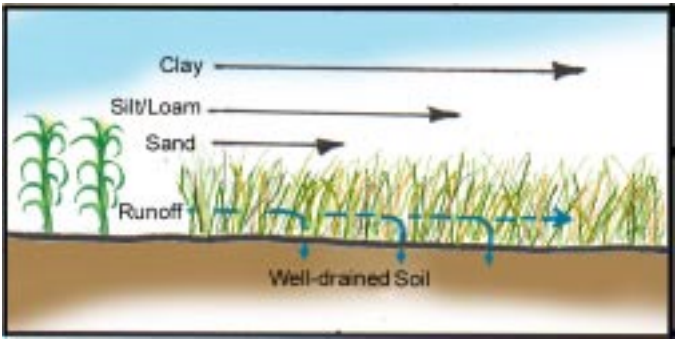
1.7 Incised Channels and Nitrate Removal

Groundwater nitrate removal will generally be less in riparian zones adjacent to incised streams due to the deep water table and lack of active hydric soils. [52]



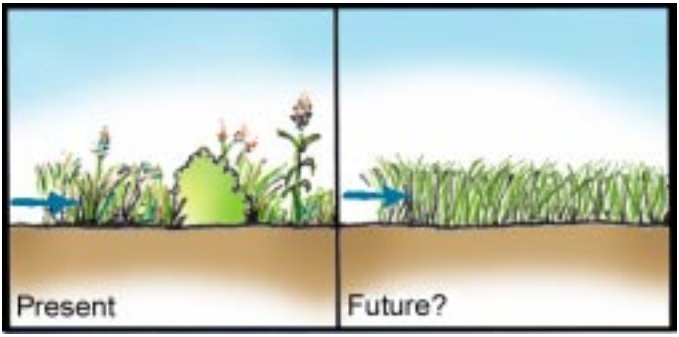
1.8 Seeps and Groundwater Nitrate Removal

The presence of seeps may limit groundwater nitrate removal by allowing flows to the surface. The flow can then travel via rivulets, quickly traversing the riparian zone and effectively bypassing treatment. In some cases, the buffer may be place immediately upslope of the seep to intercept the shallow groundwater flow. [8, 52, 62]



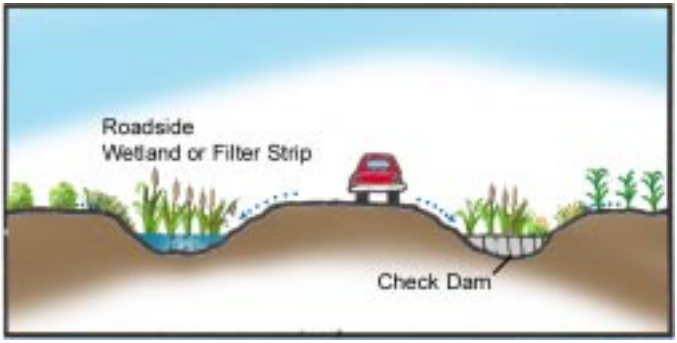
1.9 Sediment Trapping and Soil Properties

For sediment trapping, buffers should consist of dense, stiff-stemmed vegetation to slow runoff and encourage deposition. Coarser particles will settle out more quickly than fine particles. Most sediment trapping will occur in the first couple of meters. Well-drained soils encourage infiltration and enhance sediment trapping. [36, 178]



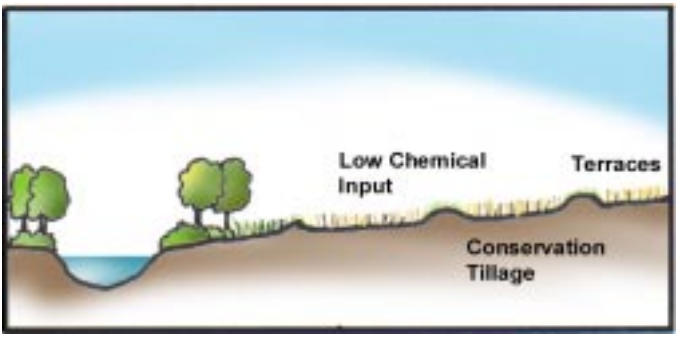
1.10 Species Change From Pollutant Loading

The plant community in a buffer receiving pollutant loads may experience a change in species composition. Pollutant loadings, particularly nitrate, will favor species that can take advantage of the highly fertile conditions and which may out compete other species in the buffer. Often, species diversity will be lower under these conditions. [31, 130, 153, 154]



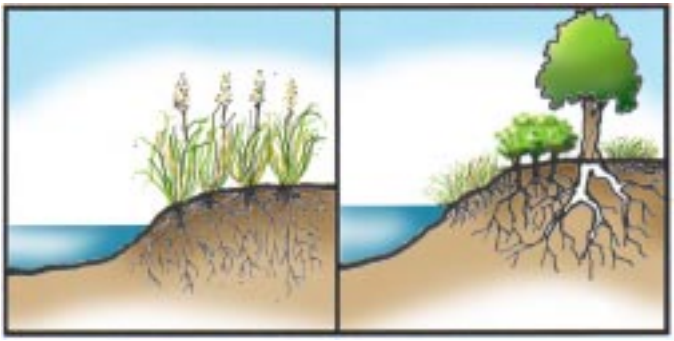
1.11 Roadsides for Water Quality

Roadsides can improve water quality by filtering runoff. Sediment can be trapped and chemical pollutants can be treated through microbial transformation and plant uptake. Hardy wetland plants may be the most suitable for these functions. Small check dams can be installed to reduce velocity, increasing residence time and overall treatment efficiency. [36, 62]



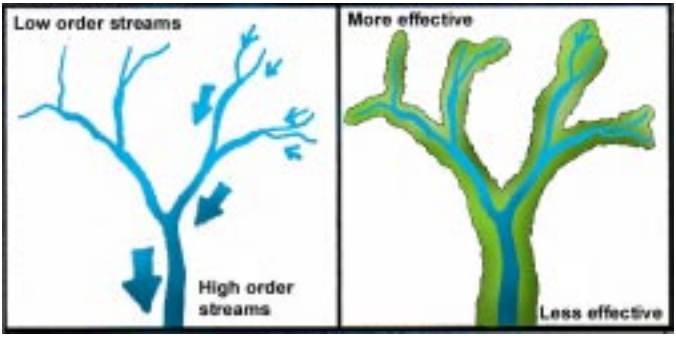
1.12 Buffers and Field Management

Buffers are more effective when adjacent fields are also managed for water quality concerns. Practices that increase infiltration, reduce water runoff and erosion, and increase soil organic matter will reduce pressure on the buffer. In addition, fertilizer and other chemical inputs should be minimized as much as possible in order to see a significant improvement in water quality. [5, 46, 62, 167]



1.13 Roots and Streambanks

Herbaceous plants with fibrous root systems are better for protecting banks from surface erosion and may encourage deposition of sediments. Trees and shrubs with deeper roots will be better at increasing soil shear strength and retarding mass slope failure. On high, steep bank, large trees may increase bank failure by adding weight and creating a lever. 5[3, 148, 172]



1.14 Watershed Location of Buffers

The majority of streams in a given watershed are 1st to 3rd order streams. Riparian buffers will often be more effective along low order streams than high order streams due to the lower input of contaminants per unit area of buffer in 1st to 3rd order streams.[8, 37, 38, 47, 63, 104, 105, 106, 160, 170]

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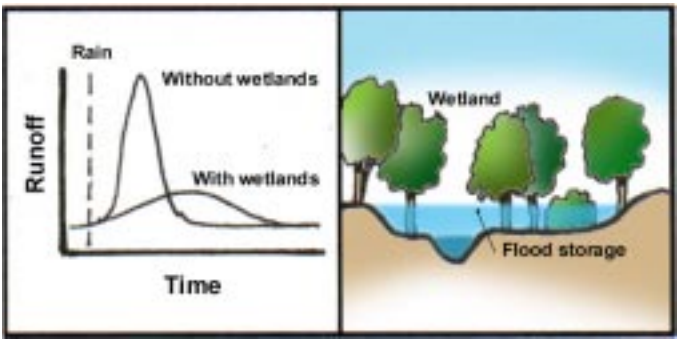
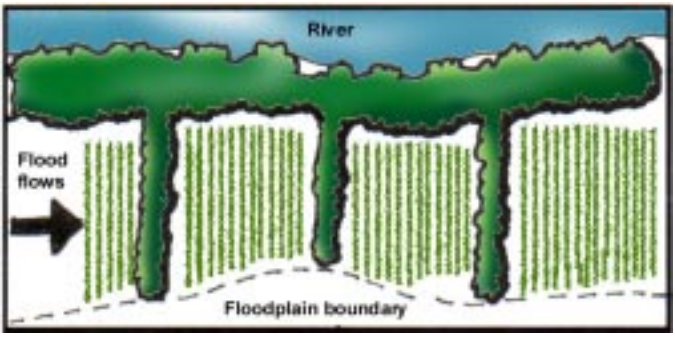


1.15 Flood Reduction and Sediment Control

During flood events, riparian buffers and wetlands can operate like giant sponges by slowing down runoff and absorbing excess water. This reduces peak flows downstream and lessens the chance of flooding, while allowing sediment to precipitate out. [44, 47]



1.16 Waterbreaks

A waterbreak is a planned floodplain system of linear woody buffers orientated to reduce flooding impacts, flow velocity, and sediment. A system includes a primary waterbreak parallel to the stream and secondary waterbreaks located perpendicular to the flood flows. The ends of these waterbreaks should tie into non-flood elevations and the primary waterbreak. [3, 40, 173]

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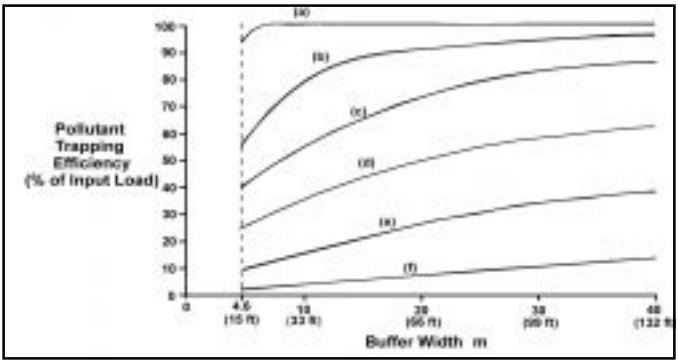


Fig. 1.17a: *Pollutant Trapping Efficiency Nomograph*

1.17 Buffer Width for Filtering Agricultural Runoff

Vegetative buffers are used to remove pollutants from surface runoff from agricultural fields. The level of pollutant removal depends upon buffer width, among other factors. This graph enables the planner to estimate a suitable width for the design of the buffer.

3-Step Method

1. Select the desired level of pollutant reduction.
2. Select the line in the adjacent graph that corresponds most closely with your site conditions.
3. Use that line to identify the buffer width that will achieve the desired level of pollutant reduction.

<u>How to select a desired level of pollutant reduction.</u>
Calculate what percentage reduction in stream pollutant level is needed to bring the existing water quality level down to a desired water quality level, such as an MCL (Minimum Concentration Limit for drinking water), TDML (Total Daily Maximum Load for the stream) or other desirable target level. This value represents the desired level of ***Pollutant Trapping Efficiency*** to design a buffer where the entire stream load comes from field runoff sources.

When stream load comes from other sources (such as livestock, urban, or industrial sources) or pathways (such as groundwater flow) the desired level of ***Pollutant Trapping Efficiency*** for cultivated land must be adjusted upward proportionally in order to achieve stream target levels by buffering surface runoff from cultivated land alone.

How to select a line in Figure 1.17a.

Figure 1.17a shows level of ***Pollutant Trapping Efficiency*** for different widths of vegetative buffer that intercept runoff from cultivated agricultural fields. Six relationships are shown (a through f) that span the range of typical expectations. (See Appendix A for a detailed explanation of how these relationships were generated).

The appropriate line to use depends on the type of pollutant and the site conditions. In general, higher pollutant trapping efficiency is obtained for sediment, smaller amounts of field runoff, and for higher capacities of a buffer to trap pollutants.

For sediment

Curve (c) represents sediment trapping by a good stand of grass for a storm event that drops 6.4 cm of rain in 1 hour on a previously wet, contour plowed, 350 m length of field having 2% slope and silt loam soil, and field runoff passes uniformly over the entire buffer.

Use curve (b) or (a) for: smaller storms, drier soils, coarser soils, small field contributing areas, and/or where additional field conservation practices are used (e.g., no-till, high residue cover). Curve (a) represents the case where almost all of the runoff from the field infiltrates in the buffer and does not reach the stream.

Use curve (d), (e), or (f) for: larger storms, steeper slopes, larger field contributing areas, finer-textured soils, where the buffer vegetation is sparse, where runoff is not uniformly distributed over the buffer, and/or where substantial amounts of field runoff bypass the buffer in ditches, pipes, or waterways. Curve (f) represents the case where buffer becomes submerged by a large amount of runoff, the buffer contains too little vegetation to slow runoff flow, and/or most runoff from the field bypasses the buffer area.

For Sediment-Bound Pollutants

Use one line lower (e.g., e instead of d) than you would use for sediment.

For Dissolved Pollutants

Use two lines lower than you would use for sediment. Trapping of dissolved pollutants is negligible in submerged buffers and where infiltration is very limited.

How to identify a suitable buffer width

Draw a horizontal line from the desired value on the axis labeled ***Pollutant Trapping Efficiency*** to the selected line in the graph (line a, b, c, d, e, or f). From that point on the line, draw a vertical line down the ***Buffer Width*** axis. The value for the ***Buffer Width*** where that vertical line intersects the axis represents the approximate design width that will achieve your desired level of pollutant trapping.

For example, to reduce the sediment load by 70% on a site with a good stand of grass for a storm that drops 6.0 cm of rain in 1 hour on wet soil, 300 m length of field having 4% slope and silt loam soil, and field runoff passes uniformly over the entire buffer, the buffer width should be approximately 20 meters (Fig. 1.17b).

The same buffer may reduce sediment-bound phosphorus by 50% and soluble nitrate by 25%.

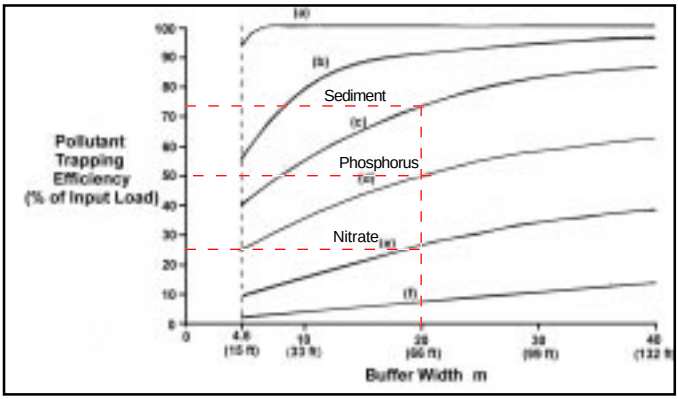


Fig. 1.17b: *Applying the Pollutant Trapping Efficiency Nomograph*

Design Hint

Design buffers for conditions that generally yield the greatest contributions of pollutant load to streams: relatively larger rainfall events, on wet soil, and below freshly plowed fields.

Appendix A

Lines a, b, c, e, and f in Figure 1.17a were derived for sediment using the filter strip model VFSMOD (Munoz-Carpena and Parsons 2000) for a range of typical farm site conditions.

The VFSMOD model is a field-scale, mechanistic, single event model that is based on the hydraulics of flow and of sediment transport and deposition.[104, 105] The sediment deposition component is based on the University of Kentucky sediment filtration model. [10, 63, 64, 160] The model assumes that field runoff flow is uniformly distributed over the buffer. Good agreement between modeled and observed trapping efficiencies has been observed for conditions in North Carolina [105], Mississippi [64], and Ontario, Canada [1].

Table 1.17: *Specific conditions modeled to produce each of the lines in Figure 1.17a.*

	SITE VARIBLES				
LINE	**Rainfall**	**Curve #**	**Slope Length**	**Slope**	**Soil**
a	4.1cm	70	400 m	2.0%	Silty clay loam
b	6.4 cm	90	74 m	3.8%	Silty clay loam
c	6.3 cm	90	350 m	2.0%	Silt loam
d	Derived by extrapolation between c and e				
e	8.9 cm	75	200 m	10.0%	Fine sandy loam
f	8.9 cm	90	400 m	10.0%	Silty clay loam

The lines were terminated at an arbitrary minimum buffer width of 4.6 meters. For comparison, the USDA-NRCS minimum recommended width for a filter strip is 6.1 meters. The lines may be extrapolated to obtain buffer widths greater than 40 meters, if needed. [36, 136]

Species & Habitats

- *Enhance terrestrial habitat*
- *Enhance aquatic habitat*

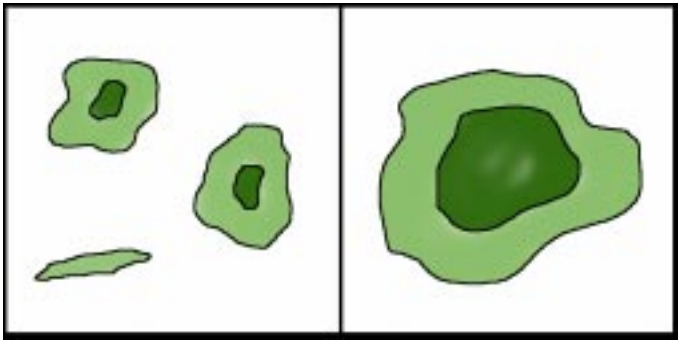
Potential Buffer Impacts on Ecological Function:

1. Increase overall habitat area
2. Protect sensitive habitats from negative impacts
3. Restore connectivity between habitats
4. Increase access to food, cover, and water resources
5. Provide shade to maintain cooler stream temperatures

	Species and Habitat Principles	Increase overall habitat area	Protect sensitive habitats from negative impacts	Restore connectivity	Increase access to food, cover, & water resources	Provide shade for cooler stream temperatures
2.1	Large patches are better than small patches.	■	■		■	
2.2	Small patches offer benefits.				■	
2.3	Several patches are better than one patch.	■			■	
2.4	Historical plant communities should guide new patches.	■				
2.5	Increase diversity in low interspersion areas.	■			■	
2.6	Introduced diversity in native plant communities should be avoided.		■		■	
2.7	Edge diversity.				■	
2.8	Edge diversity for habitat protection.		■			
2.9	Unified patches are better than fragmented patches.		■			
2.10	Variable edge width.		■			
2.11	Interior area and edge.	■	■			

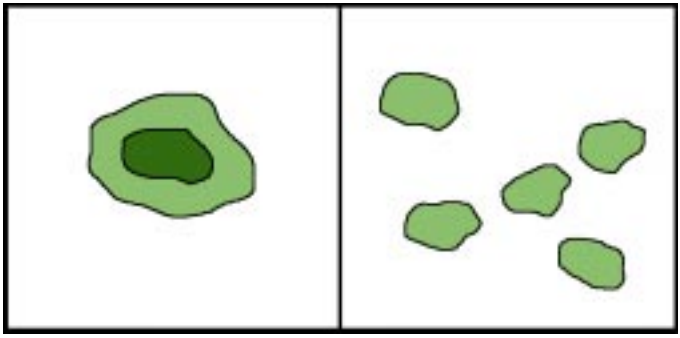
Species and Habitat Principles	Increase overall habitat area	Protect sensitive habitats from negative impacts	Restore connectivity	Increase access to food, cover,& water resources	Provide shade for cooler stream temperatures
2.12 Connected patches are better than separated patches.			■		
2.13 Nearness is better than separation.			■		
2.14 Creating effective connectivity.			■		
2.15 Stepping stone connectivity.			■		
2.16 Stepping stone distance.			■		
2.17 Natural connectivity should be maintained or restored.			■		
2.18 Patch orientation.			■		
2.19 Wider corridors are better than narrow corridors.	■	■	■	■	
2.20 Focus on gaps away from roads.			■		
2.21 Continuous stream corridors.			■		
2.22 Focus on higher order stream gaps.			■		
2.23 Roadsides for wildlife and plants.	■			■	
2.24 Roadside management for habitat.	■			■	
2.25 Roads and species movement.			■		
2.26 Retain fence lines.				■	
2.27 Stream temperature and buffers.					■

Other Principles Related to Species and Habitat	Increase overall habitat area	Protect sensitive habitats from negative impacts	Restore connectivity	Increase access to food, cover,& water resources	Provide shade for cooler stream temperatures
1.3 Constructed wetlands for tile drainage.	■			■	
7.2 Recreational trails along riparian corridors.		■			
7.3 Trail design and sensitive areas.		■			



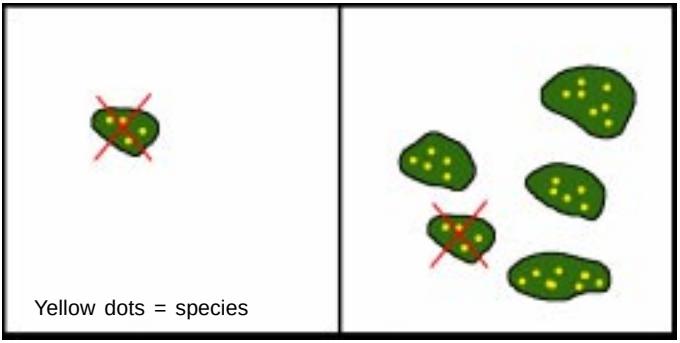
2.1 Large Patches Are Better Than Small Patches

Large patches typically preserve a greater variety and quality of habitats, resulting in higher species diversity and abundance. Large patches increase positive area effects while minimizing negative edge effects for interior dwelling species. [4, 6, 23, 32, 66, 135, 181]



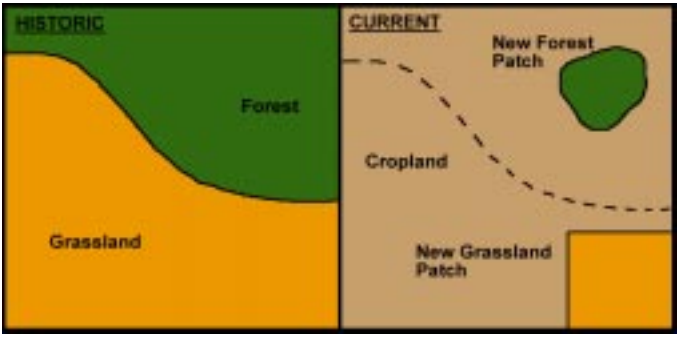
2.2 Small Patches Offer Benefits

Small patches that interrupt extensive homogeneous stretches of matrix can serve as habitat and as stepping stones for species movement even if the patches consist only of edge habitat. Both large and small patches should be part of a conservation plan. [32, 49, 163]



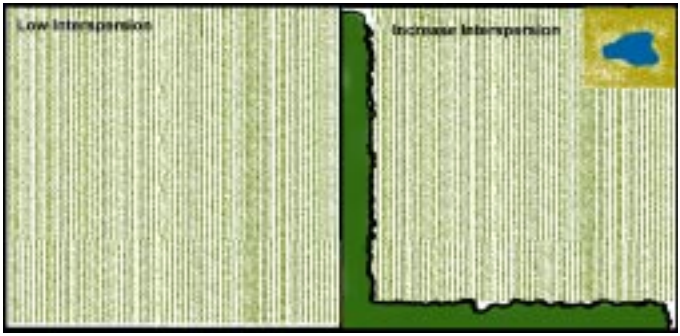
2.3 Several Patches Are Better Than One Patch

Redundancy is an essential component of healthy ecosystems at all scales. If several patches exist in an area, one of those patches can be lost without seriously threatening the species viability in the other patches. [4, 32, 190]



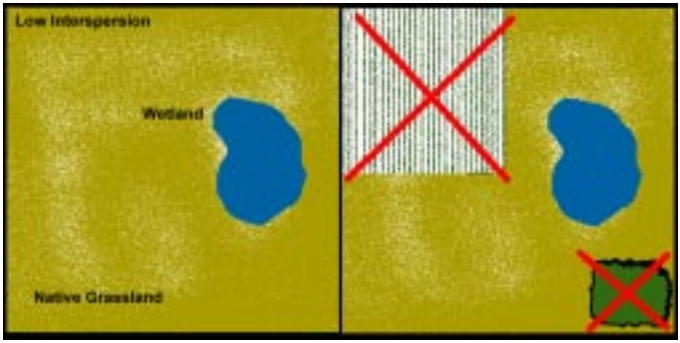
2.4 Historical Plant Communities Should Guide New Patches

Historical native vegetation patterns can indicate the type of plant communities suitable for new habitat patches. These types of plant communities will be best suited to the soils, climate, and other site characteristics. [41, 151]



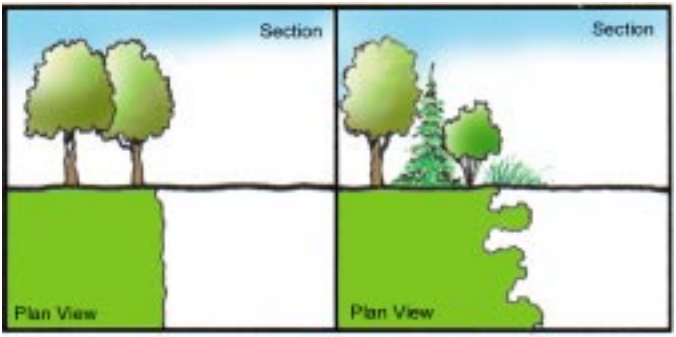
2.5 Increase Diversity in Low Interspersion Areas

Areas with low interspersion of land cover types provide few opportunities for species requiring a variety of habitats. Increasing diversity by creating new habitat patches can benefit these species. Areas with high interspersion of land cover types can be protected in order to benefit species requiring a variety of habitat types.[86, 158]



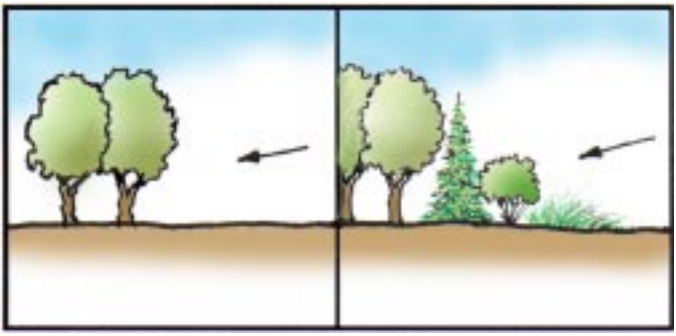
2.6 Introduced Diversity in Native Plant Communities Should Be Avoided

Low interspersion can be beneficial to wildlife if the area is dominated by native vegetation. Introducing diversity in these areas may be harmful to native wildlife, particularly for specialist species.[41, 66, 135]



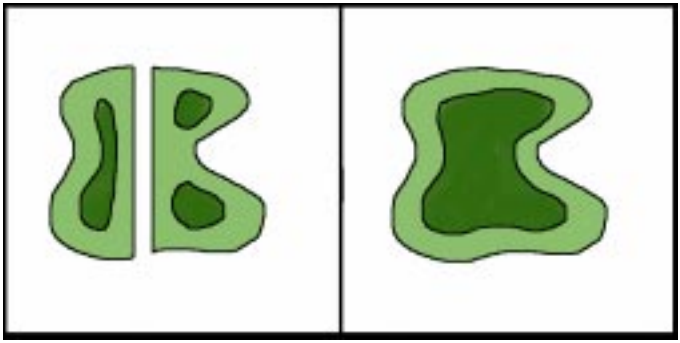
2.7 Edge Diversity

Vegetative edges with high structural diversity, both vertically and horizontally, are richer in edge animal species. These diverse edges provide numerous niches for species. [6, 129]



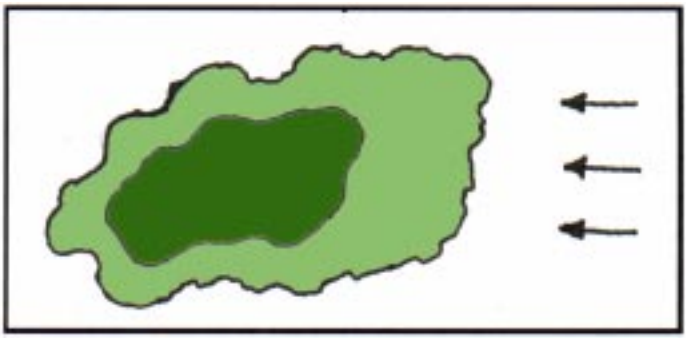
2.8 Edge Diversity For Habitat Protection

Vegetative edges with high structural diversity may protect interior habitat from negative edge effects better than edges with limited structural diversity. Parasitism and negative microclimate effects seem to be less in these situations. [16, 129]



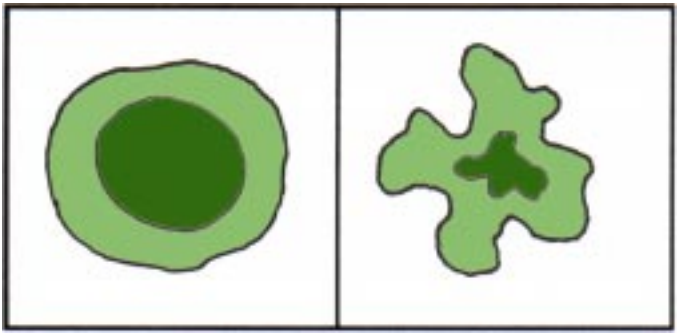
2.9 Unified Patches Are Better Than Fragmented Patches

Of two patches having exactly the same area, one fragmented and one unified, the unified patch will be of far greater value. There will be less edge and therefore potential negative edge effects will be minimized. [4, 6, 16, 32, 135]



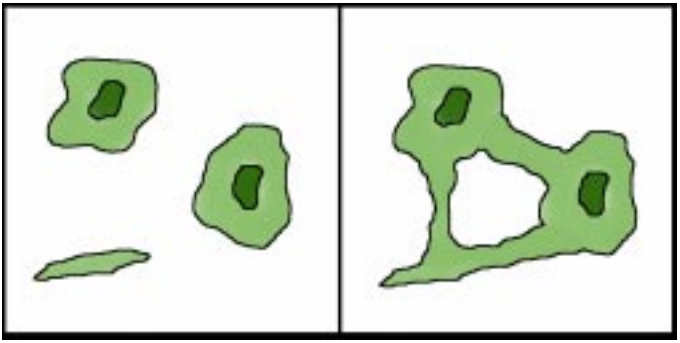
2.10 Variable Edge Width

Edge width will vary around a patch. Edge effects will generally be wider on sides facing the predominant winds and solar exposure. [16, 20, 94, 148, 181]



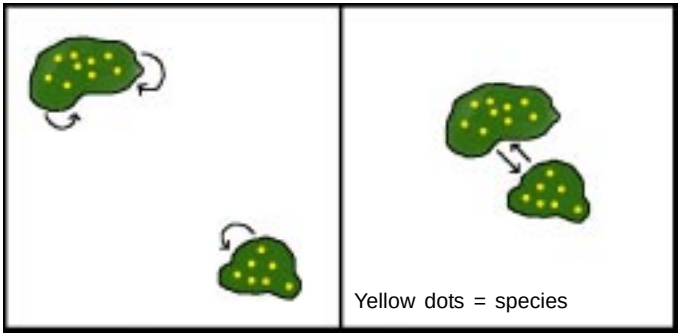
2.11 Interior Area and Edge

A convoluted patch will have a higher proportion of edge habitat, increasing the number of edge species while decreasing the number of interior species. [6, 32, 129, 135]



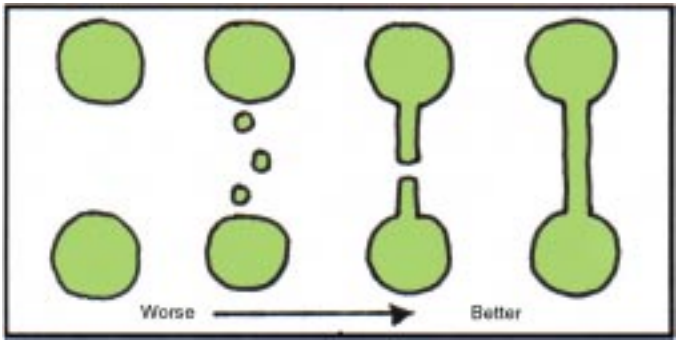
2.12 Connected Patches Are Better Than Separated Patches

Connected patches provide wildlife populations access to large total areas of habitat, increasing population numbers and viability of individual populations and metapopulations. [32, 55, 56, 57, 66, 135, 174]



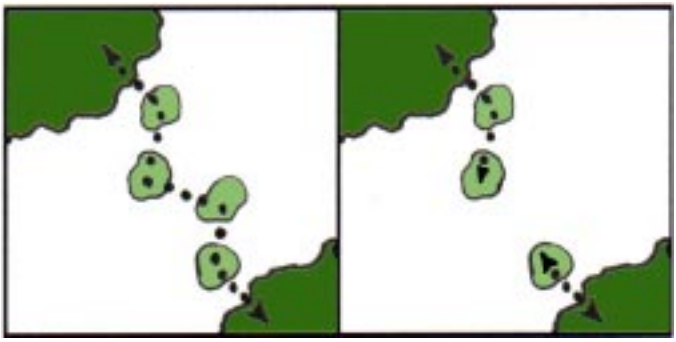
2.13 Nearness Is Better Than Separation

Opportunities that species inhabiting patches will interact becomes disproportionately greater as the distance between patches decreases. This potential interaction is dependent on species and their movement capabilities. [4, 6, 81, 135]



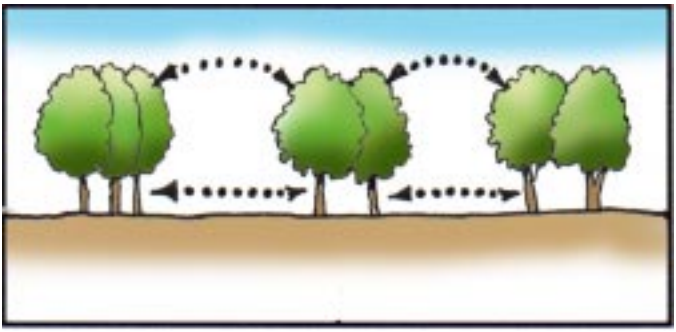
2.14 Creating Effective Connectivity

Connectivity between patches is more effective with completed corridors. The effect of a gap in a corridor on movement of a species depends on the length of the gap relative to the scale of species movement. [23, 55, 56, 57, 90, 174]



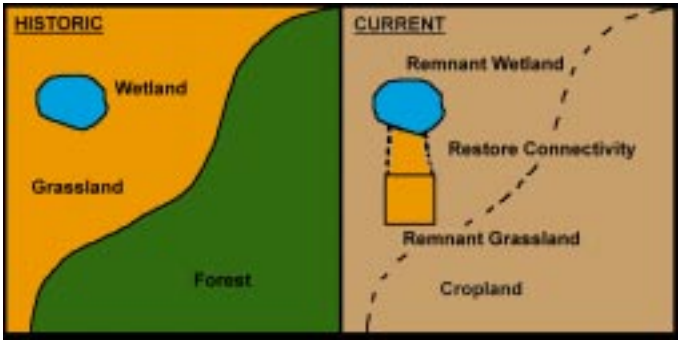
2.15 Stepping Stone Connectivity

Small patches can serve as stepping stones, allowing species movement between large patches. The loss of one stepping stone can often inhibit movement, increasing patch isolation. [28, 57]



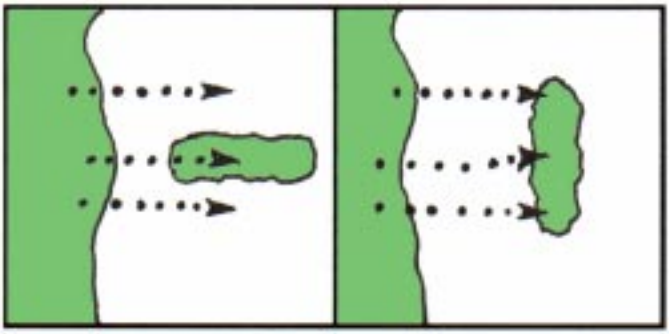
2.16 Stepping Stone Distance

For highly visually-orientated species, the effective distance for movement between stepping stones may be determined by the ability to see each successive stepping stone. [28, 57, 131]



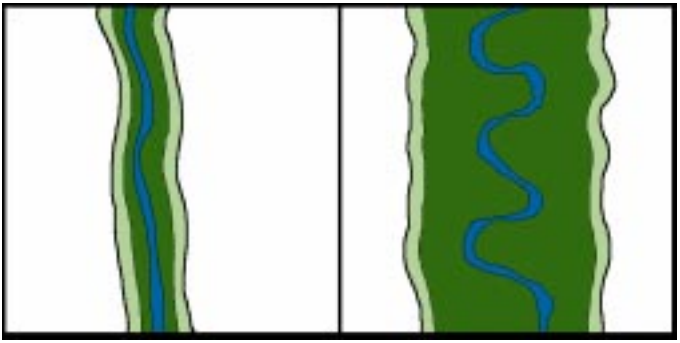
2.17 Natural Connectivity Should be Maintained or Restored

Maintaining historical connections between patches is essential in conserving species diversity and population viability. In many cases, it may be necessary to restore historical connections. Although connected is better than fragmented, care must be taken when linking historically disconnected patches. Undesirable predation and population mixing may occur otherwise. [23, 90, 135]



2.18 Patch Orientation

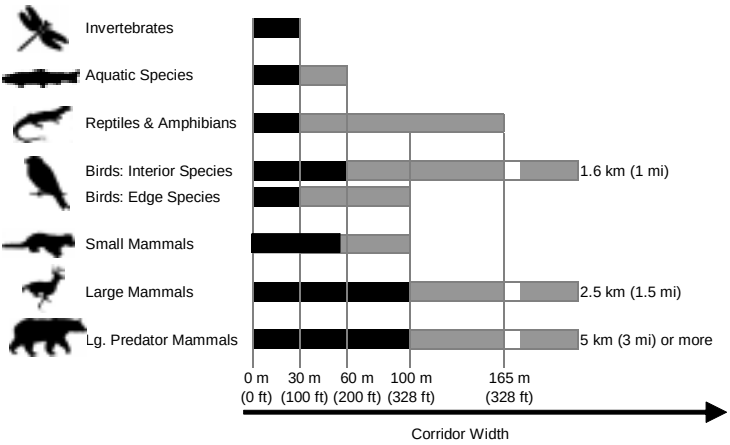
Patches perpendicular to the flow of the dispersing individuals will have a higher probability of intercepting the individuals than patches oriented with the long axis parallel to the flow. [54]

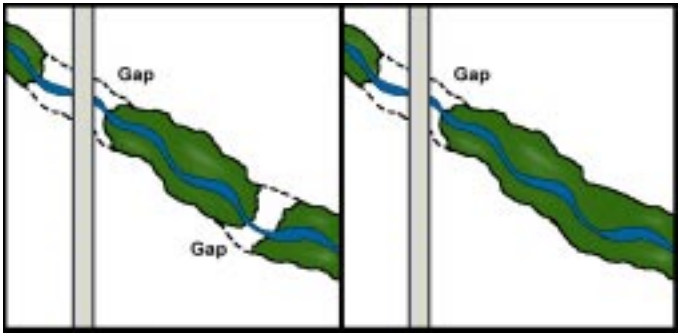


2.19 Wider Corridors Are Better Than Narrow Corridors

Wide corridors, both upland and riparian, provide greater habitat area with reduced edge effects, while promoting greater species movement. Wider stream corridors facilitate meandering and bank stability, providing overall higher habitat quality.

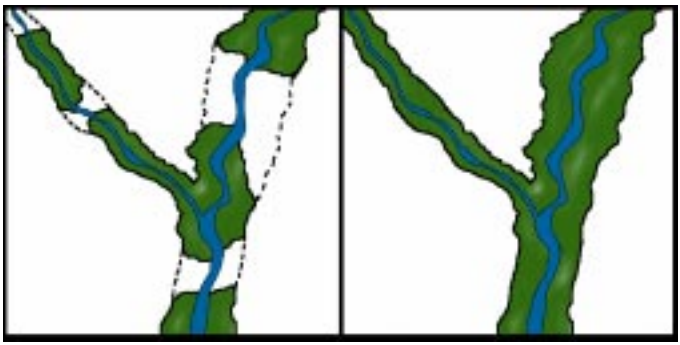
The figure below summarizes research on species movement through corridors. The black bar denotes the suggested minimum corridor width while the grey bar indicates the upper end of recommended widths. In general, the larger the species, the wider the corridor will need to be for that species. Also, as the length of the corridor increases, so should the width. While corridor width is important, habitat type and quality of the corridor play a significant role as well. [18, 27, 33, 42, 44, 58, 70, 72, 79, 80, 89, 90, 92, 103, 122, 128, 133, 139, 140, 147, 155, 161, 168]





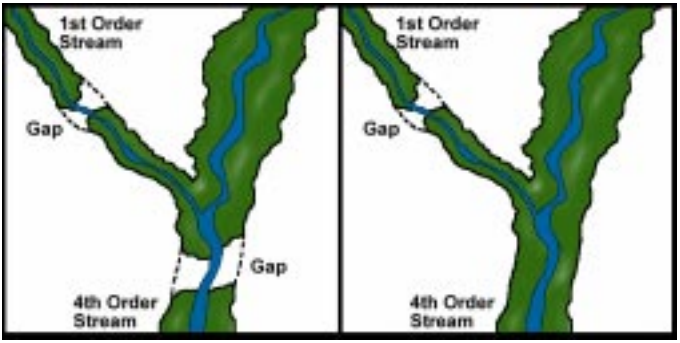
2.20 Focus on Gaps Away From Roads

Because roads can often be barriers to species movement, efforts should first focus on restoring gaps away from roads. [7, 162]



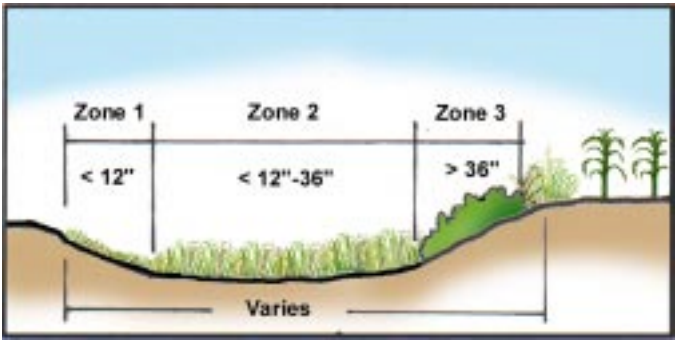
2.21 Continuous Stream Corridors

Gaps in stream corridors can disrupt terrestrial and aquatic species movement and can allow negative edge effects. Gaps also diminish the effectiveness of the corridor to serve as a filter. [18, 46, 48, 111]



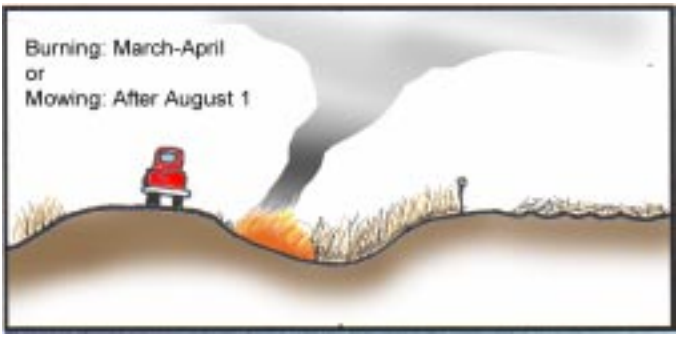
2.22 Focus on Higher Order Stream Gaps

When prioritizing riparian revegetation efforts, concentrate on higher order streams. Higher order streams will generally provide greater benefits for biodiversity due to increased habitat area. [18, 46, 48, 111, 170]



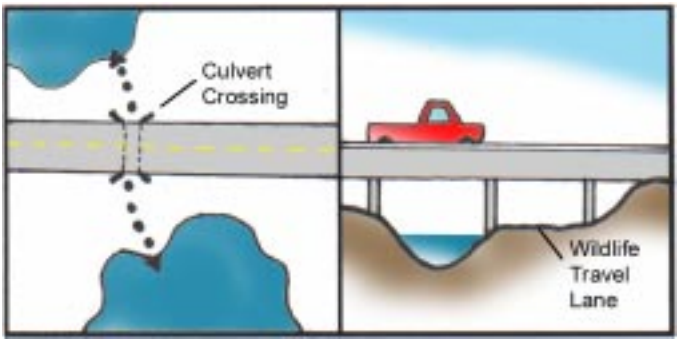
2.23 Roadsides for Wildlife and Plants

By using a zonation approach and managing vegetation height, roadsides can provide suitable habitat for many species while minimizing potential collisions between vehicles and wildlife. As road speed increases, width of zones needs to increase. [19, 45, 117, 131, 159]



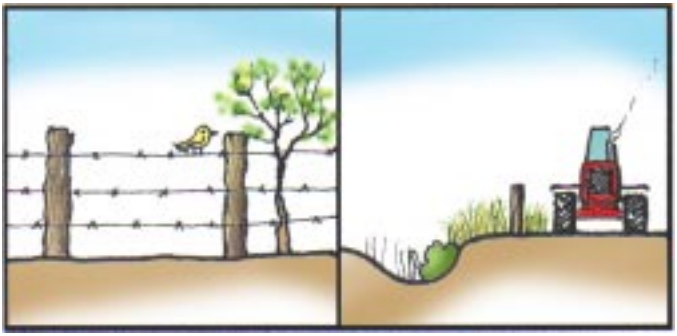
2.24 Roadside Management for Habitat

Roadsides should be planted with native plants to provide wildlife habitat. Maintain plant vigor and species richness by either mowing or burning the roadsides every 1-3 years. Both burning or mowing should be done in blocks along the roadside to ensure some portion remains undisturbed at all times. [19, 45, 121]



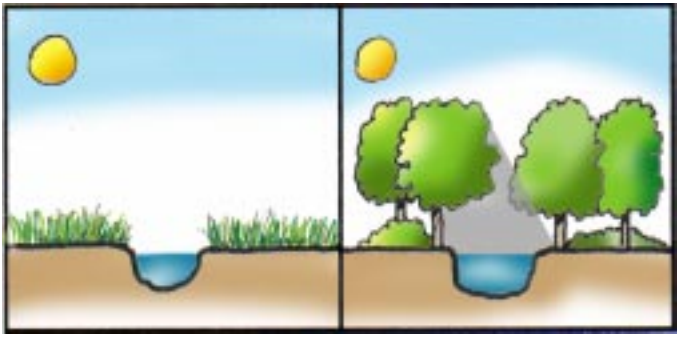
2.25 Roads and Species Movement

Both desirable and invasive species can use roadsides for movement. Small species like amphibians may use roadside ditches for travel corridors. Culverts, bridges, and other structures can be designed to allow safe passage across the roads. Passages should be designed for multiple species when possible. [51, 159]



2.26 Retain Fence Lines

Fence lines should be retained because roadsides are less susceptible to agricultural encroachment (i.e. cultivation and herbicide spraying). Fence lines also serve as value perches for birds. Overtime, a woody corridor may develop along the fence line from seeds in bird droppings. This may be desirable or undesirable depending on species of interest. [19, 45]



2.27 Stream Temperature and Buffers

Buffers can help maintain or lower water temperatures in small, narrow streams if the buffer provides adequate shade on most of the water surface. Cooler water temperatures will increase the dissolved oxygen (DO) content in the stream and may be beneficial for certain aquatic species. [11, 68, 78]

Stable and Productive Soils

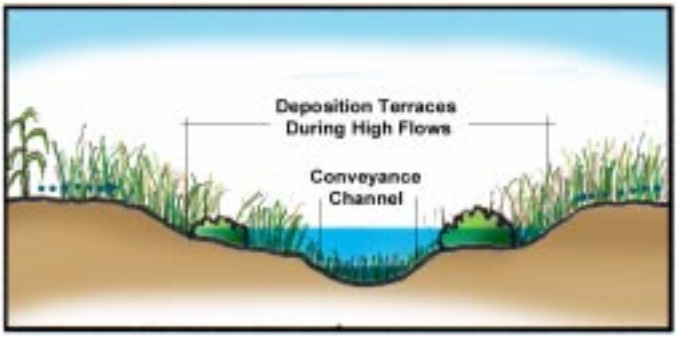
- *Reduce soil erosion*
- *Increase soil productivity*

Potential Buffer Impacts on Ecological Function:

1. Reduce water runoff energy
2. Reduce wind energy
3. Stabilize soil particles
4. Increase organic matter
5. Increase infiltration

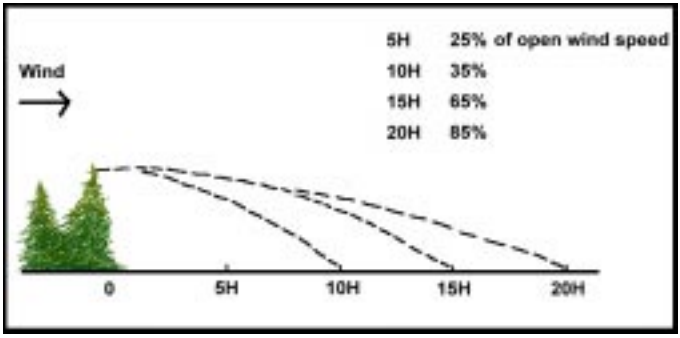
Stable and Productive Soil Principles	Reduce water runoff energy	Reduce wind energy	Stabilize soil particles	Increase organic matter	Increase Infiltration
3.1 Conveyance zones and sediment.	■		■		
3.2 Wind energy reduction.		■	■		
3.3 Buffers and Infiltration.					■
3.4 Water Erosion Prediction Project.	■				
3.5 Residue management: buffers.	■	■	■		
3.6 Residue management: erosion.	■	■	■		
3.7 Residue management: soil moisture.	■			■	■
3.8 Residue management: organic matter.				■	

Other Principles Related to Stable and Productive Soils	Reduce water runoff energy	Reduce wind energy	Stabilize soil particles	Increase organic matter	Increase Infiltration
1.1 Filter vegetation should be non-dormant during runoff season.	■		■		
1.9 Sediment trapping and soil properties.	■	■			
1.12 Buffers and field management.	■	■	■	■	■
1.13 Roots and streambanks.	■			■	■
1.15 Flood reduction and sediment control.					
2.21 Continuous stream corridors.	■		■		
2.26 Retain fence lines.	■	■	■	■	■
5.8 Trees and levees.	■		■		
5.9 Carbon sequestration.				■	
7.7 Soil characteristics and trail recreation.	■	■	■	■	■



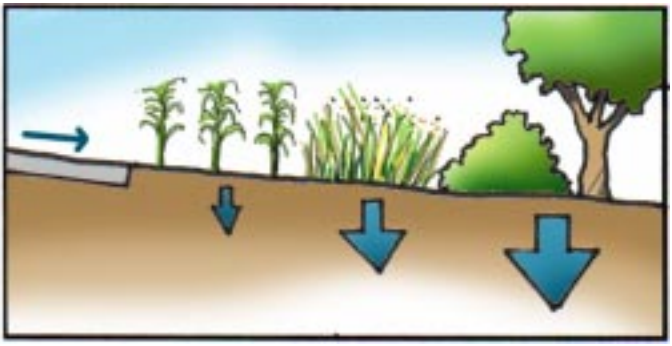
3.1 Conveyance Zones and Sediment

Conveyance zones such as grass waterways can be designed to capture and retain sediment. Benches or terraces adjacent to the channel can serve as deposition areas during high flow events and for flows from adjacent fields. Vegetative barriers can also be placed perpendicular to flow lines to reduce velocity and increase deposition. [36, 37, 38, 160, 178]



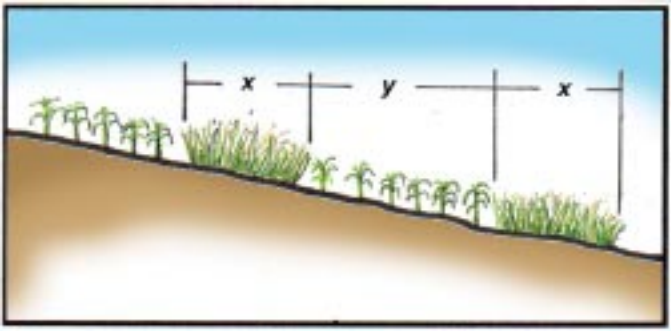
3.2 Wind Energy Reduction

The height of the windbreak influences the reduction in wind energy. The greatest reduction generally occurs at a distance of 10 to 15 times the height of the windbreak. Barriers with a porosity of 40-50% reduces soil erosion while barriers with 60-75% porosity achieve a more even distribution of snow deposition. [15, 65, 138]



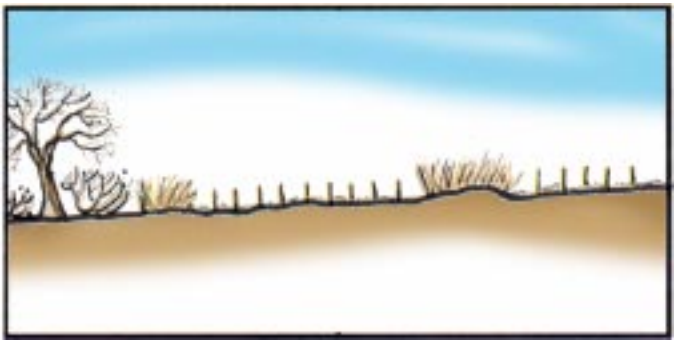
3.3 Buffers and Infiltration

Permanent vegetation in buffers can significantly increase the infiltration capacity of soils within the buffer zone compared to adjacent cropland or pastures. Species that have high moisture requirements may be the best for decreasing soil moisture, thus increasing infiltration capacity. Grazing in the buffer should be avoided since this dramatically reduces infiltration due to compaction by hoof action. [13, 105]



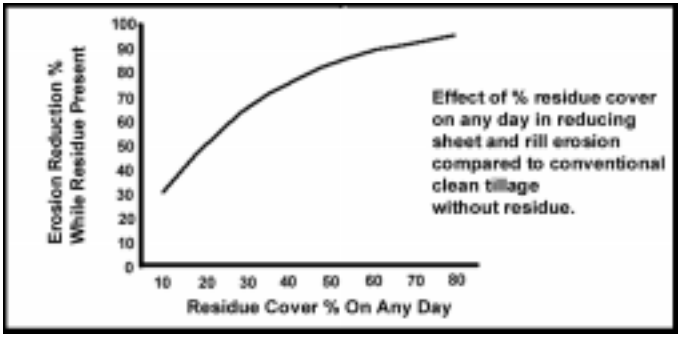
3.4 Water Erosion Prediction Project

The Water Erosion Prediction Project (WEPP) allows users to predict soil loss based on soil types, climate, topography, management practices and the use buffers or filter strips. The effect of buffers placed at the end of a hillslope or alternating with crops along a hillslope can be simulated. [21, 85, 114]
This simple web-based tool can be accessed at
http://octagon.nserl.purdue.edu/weppV1



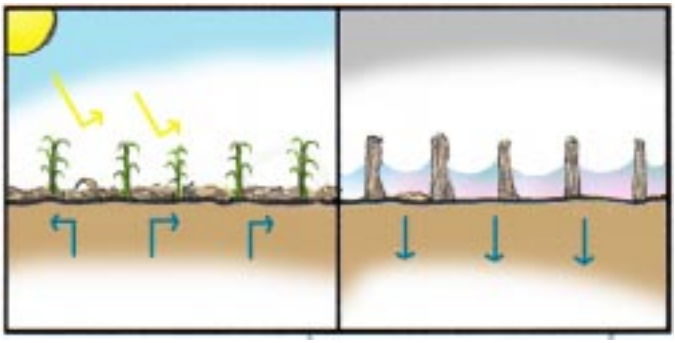
3.5 Residue Management: Buffers

Buffers can overcome problems associated with inappropriate crop residue management. Trapping soil in buffers is generally ineffective in maintaining soil productivity in the field and can become a long-term maintenance issue. The most effective approach for stable and productive soils is to design the conservation system to incorporate buffers and in-field management. [46]



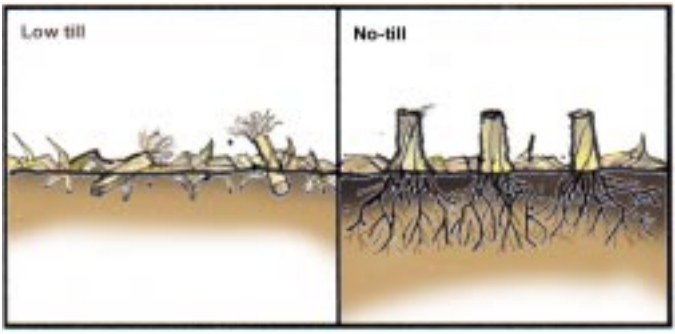
3.6 Residue Management: Erosion

Leaving crop residue on the soil surface reduces sheet and rill erosion by reducing the splash effect and surface runoff, while increasing infiltration. Crop residue can also reduce wind erosion. With low residue crops, residue should be left standing and orientated perpendicular to the prevailing wind direction. [14, 87, 108]



3.7 Residue Management: Soil Moisture

Crop residue on the soil surface can effectively reduce evaporation and increase infiltration due to soil aggregation. In addition, standing residue can capture drifting snow. Research on the northern Great Plains showed that high residue management systems can save 2-4 inches of soil moisture. Each inch of moisture saved increased wheat yields by about 5 bushels per acre. [73, 74, 108]



3.8 Residue Management: Organic Matter

Recent research indicates that most of the increase in soil organic matter is the result of leaving undisturbed root biomass, not just leaving crop residue on the surface. Increasing the soil organic matter raises the cation exchange capacity, allowing soils to hold more plant nutrients. Healthier soils also results in healthy plants and less damage by pest species. [73, 74, 87]

Economic Opportunities

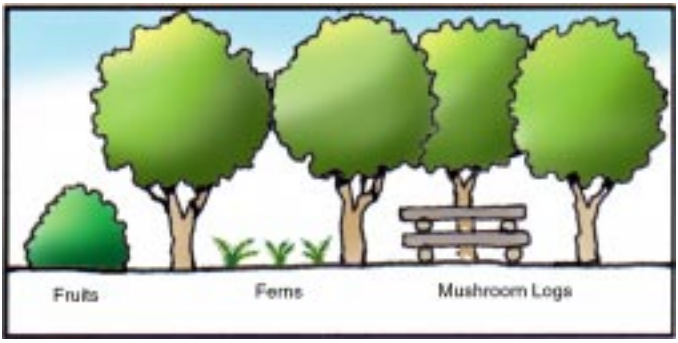
- *Provide alternative income sources*
- *Increase economic diversity*
- *Increase economic value*

Potential Buffer Impacts on Ecological Function:

1. Grow marketable products
2. Enhance habitat for marketable wildlife
3. Reduce energy consumption
4. Increase property values
5. Increase crop yields

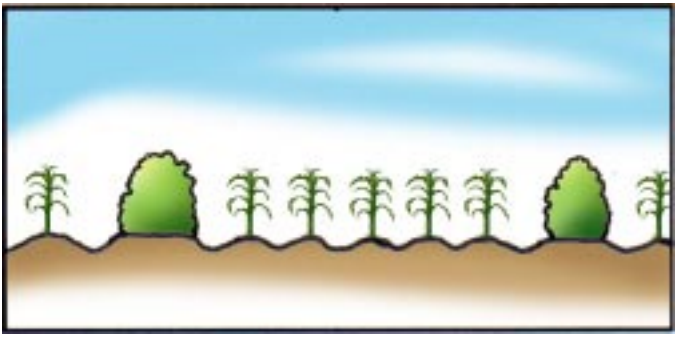
Economic Opportunities Principles	Grow marketable products	Enhance habitat for marketable wildlife	Reduce energy consumption	Increase property values	Increase crop yields
4.1 Multi-species forest farming.	■				
4.2 Alley cropping.	■				
4.3 Remnants have value.	■	■		■	
4.4 Buffers and property values.				■	
4.5 Buffers and crop yields.					■
4.6 Crop pollinators.		■			■
4.7 Economic impact of trails.				■	
4.8 Energy savings.			■		

Other Principles Related to Economic Opportunities	Grow marketable products	Enhance habitat for marketable wildlife	Reduce energy consumption	Increase property values	Increase crop yields
2.0 All species and habitat principles		■			
3.2 Wind energy reduction.	■				■
3.7 Residue management: soil moisture.	■				■
3.8 Residue management: organic matter.	■				■
5.1 Use buffers to concentrate weed species.	■				■
5.2 Use buffers to manage pest species.	■				■
5.3 Select plants that attract beneficial insects	■				■
5.7 Windbreaks for livestock.	■		■		
6.2 Buffers for visual diversity.				■	
6.4 Buffers for visual screening.				■	
6.5 Buffers for noise reduction.				■	
6.6 Visual variety.				■	
6.7 Buffers for air contaminants.				■	
6.8 Design to be visually compatible.				■	



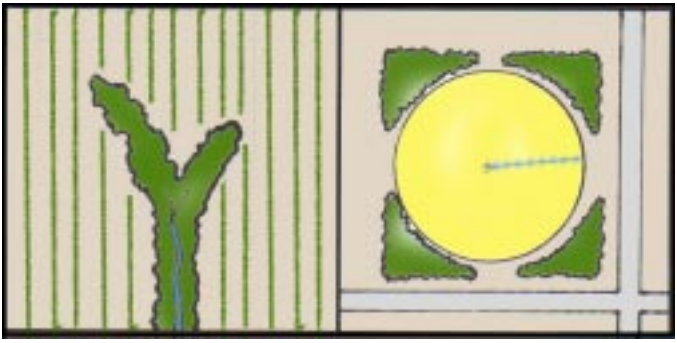
4.1 Multi-species Forest Farming

Forested buffers can be used for growing speciality crops under the canopy. A variety of medicinal, food, and decorative products can be grown and harvested from understory, mid-story, and overstory environments. Often the best strategy is to combine short and long-term products like medicinal herbs and timber production. [69, 132, 175]



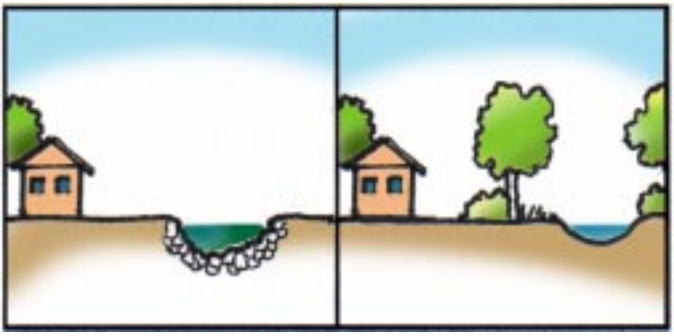
4.2 Alley Cropping

Alley cropping is the planting of trees or shrubs in rows with agronomic, horticultural or forage crops cultivated in the alleys between the rows of woody plants. The woody plants can provide marketable products while protecting the other crops. [50, 169]



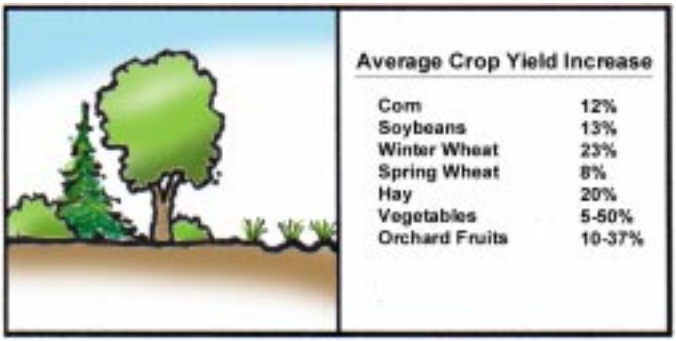
4.3 Remnants Have Value

Remnant areas such as irrigation pivot corners and riparian corridors can provide economic opportunities. Christmas trees, decorative woody florals, native wetland forb and grass seeds are just some of the products that can be grown and harvested from these areas. For products with local interest, u-pick operations may be one alternative for landowners with limited time to manage remnant areas. [64, 132, 134, 182]



4.4 Buffers and Property Values

Studies have shown that restored riparian corridors can increase property values by 14% while greenways with recreational trails can increase property values by 32%. Generally, a wider corridor with visual diversity corresponds to a larger increase in property values. [26, 150]

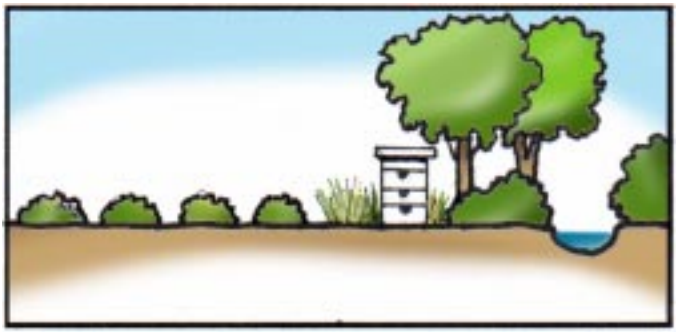


Average Crop Yield Increase

Corn	12%
Soybeans	13%
Winter Wheat	23%
Spring Wheat	8%
Hay	20%
Vegetables	5-50%
Orchard Fruits	10-37%

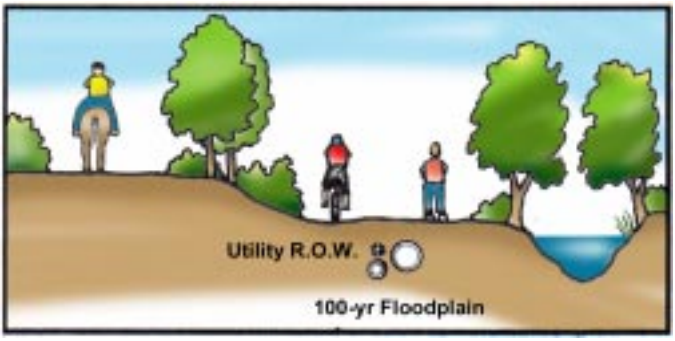
4.5 Buffers and Crop Yields

Buffers can significantly increase crop yields due to reduced wind erosion, improved microclimate, snow retention, and reduced crop damage by high winds. [9, 83] Windbreak design parameters and crop benefits can be calculated using a WBECON, a model available at : http://waterhome.brc.tamus.edu/NRCSdata/models/Forest and Windbreaks/WB/.



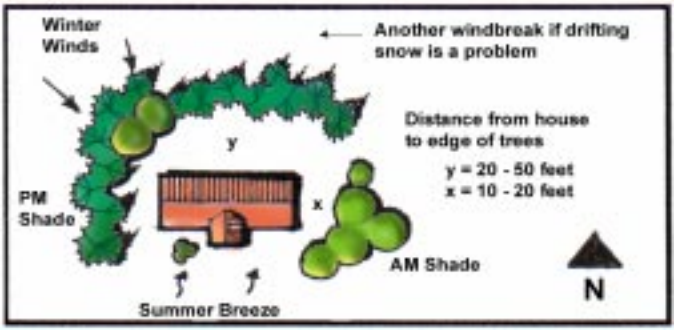
4.6 Crop Pollinators

Pollinators play a major role in the production of over 150 food crops in the U.S. such as apples, alfalfa, melons, squash and blueberries. Primary pollinators for crops include bees, moths, butterflies, birds, and bats. Buffers can provide pollinator habitat by including shade and water sources. Buffers should be distributed throughout the field area to minimize negative effects of wind on pollinator movement. [109, 146]



4.7 Economic Impact of Trails

Buffers that incorporate trails or greenways can generate significant income for local economies through increase in property values, expenditures by residents, tourism, agency expenditures, and public cost reduction. Trails can reduce public costs by serving as utility corridors and protecting hazardous areas (flood and fire prone, slope instability) from development. [26, 110] Information on benefit estimation can be found at http://www.americantrails.org/resources/economics/



4.8 Energy Savings

Buffers planted with the right type of trees and proper location can yield heating and cooling energy savings by 20-30%. Summer shading is best accomplished on the east and west sides but avoid shading the south windows in the winter. Create windbreaks to block harsh winter winds but that allow cool summer breezes to blow through the property. [30, 96]

PROTECTION AND SAFETY

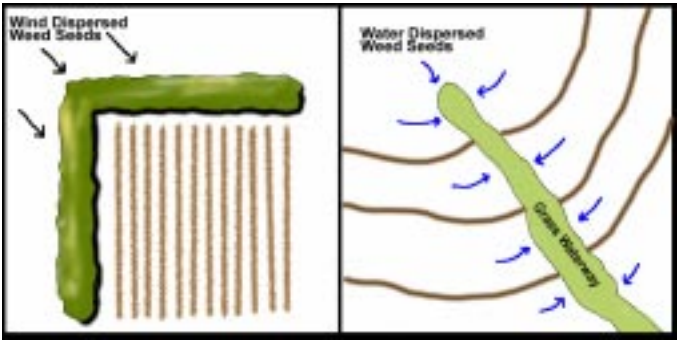
- *Protect or manage wind or snow*
- *Increase biological control of pests*
- *Protect from floodwaters*

Potential Buffer Impacts on Ecological Function:

1. Reduce wind energy
2. Modify microclimate
3. Manage habitat for biological pest management
4. Reduce erosive force of floodwaters

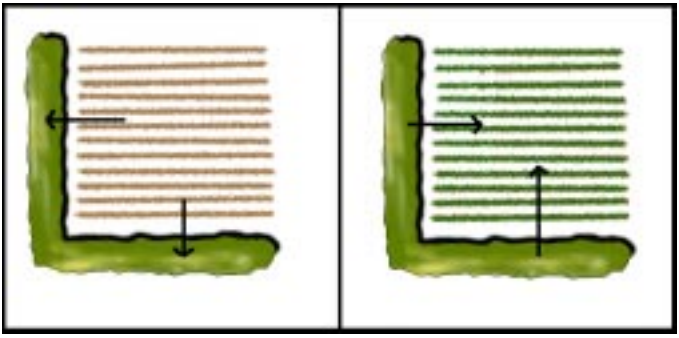
Protection and Safety Principles	Reduce wind energy	Modify microclimate	Manage habitat for pest management	Reduce erosive force of floodwaters	Create safe environment
5.1 Use buffers to concentrate weed species.	■		■		
5.2 Use buffers to manage pest species.	■		■		
5.3 Select plants that attract beneficial insects.		■			■
5.4 Buffers and road ice.					■
5.5 Buffers and road intersections.					■
5.6 Managing drifting snow.	■				■
5.7 Windbreaks for livestock.	■	■			
5.8 Trees and levees.				■	■
5.9 Carbon sequestration.					■

Other Principles Related to Protection and Safety	Reduce wind energy	Modify microclimate	Manage habitat for pest management	Reduce erosive force of floodwaters	Create safe environment
1.15 Flood reduction and sediment control.				■	
1.16 Waterbreaks				■	
2.2 Small patches offer benefits.			■		
2.3 Several patches are better than one patch.			■		
2.5 Increase diversity in low interspersion areas.			■		
2.13 Nearness is better than separation.			■		
2.14 Creating effective connectivity.			■		
2.18 Patch orientation.			■		
3.1 Conveyance zones and sediment.					
3.2 Wind energy reduction.	■	■	■		
4.3 Remnants have value.			■		
4.5 Buffers and crop yields.	■	■			



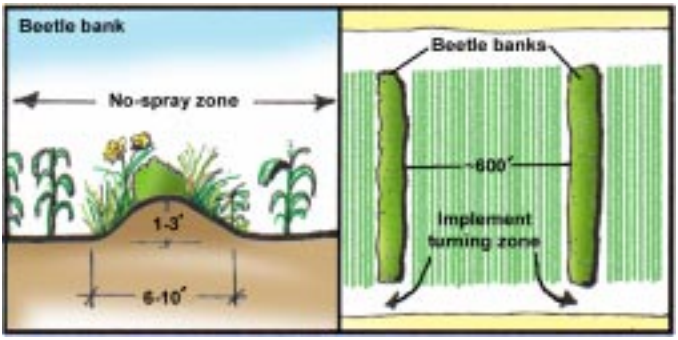
5.1 Use Buffers To Concentrate Weed Species

Buffers can be used to collect and concentrate water and wind dispersed weed seeds. This can minimize the area required for active weed treatment and management. [45, 51, 159]



5.2 Use Buffers To Manage Pest Species

Buffers can be used to concentrate pest species, minimizing the area for pest treatment and management. Buffers can also be used to harbor desirable predatory insects that can control pest species. [12, 35, 93, 97, 116, 124, 157, 163, 179]



5.3 Select Plants That Attract Beneficial Insects

Certain plant species attract beneficial insects that prey on pest insects that harm crops. Buffers can be planted with these plants to provide habitat for the desirable insects to minimize damage by pest insects. The key is to establish a diversity of plant species that provide habitat needs throughout the year, particularly for helping beneficial insects to over winter.

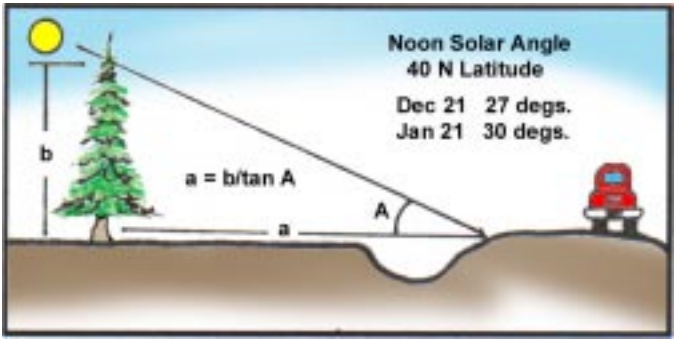
Beetle banks are one way to create beneficial insect habitat using plants. These graded low banks run the length of fields and are place approximately 600 feet apart to provide easy access to the crop for the beneficial insects. The banks are slightly mounded to prevent the insect habitat from flooding. These habitats are very susceptible to pesticide drift and therefore a no-spray zone should be established around the beetle banks. [17, 29, 91, 124]

Plants that Attract Beneficial Insects		
Beneficial	**Pests**	**Plants**
Assassin bug (Reduviidae family)	Many insects including flies large caterpillars	Permanent plantings for shelter (e.g. windbreaks, riparian buffers)
Braconid wasp (Braconidae family)	Armyworm, cabbageworm, codling moth, gypsy moth, European corn borer, aphid, caterpillars, and other insects	Nectar plants with small flowers (caraway,, fennel, mustard, white clover, tansy, yarrow), sunflower, hair vetch, spearmint
Ground beetle (Carabidae family)	Slug, snail, cutworm, Colorado potate beetle, gypsy moth and tent caterpillar	Amaranth, white clover. Permanent plantings for shelter (e.g. windbreaks, riparian buffers)

Plants that Attract Beneficial Insects		
Beneficial	**Pests**	**Plants**
Lacewing (*Chrysoperla and Chrysopa spp.*)	Soft bodied insects including aphid, thrips, mealybug, scale, caterpillars, mite)	Carrot family (caraway, tansy, dill, angelica), sunflower family (coreopsis, cosmos, sunflowers, dandelion, goldenrod), buckwheat, corn
Ladybug beetle (*Hippodarmia spp.* and others)	Aphid, spider mite, mealybug	Sunflower family (goldenrod, coreopsis, sunflower) native grasses, black locust
Minute Pirate Bug (Anthocorid family)	Thrips, spider mite, leafhopper, corn earworm, small caterpillars, and other insects	Carrot family (chervil, tansy, dill, bishop's weed), sunflower family (daisies, cosmos, sunflowers, yarrow, goldenrod), buckwheat, corn, hairy vetch, blue elderberry, willows and other shrubs.
Spider	Many insects	Caraway, dill, fennel, cosmos, marigold, spearmint
Syrphid fly (hover flies)	Aphid	Carrot family (fennel, tansy, dill, bishop's weed, parsley), sunflower family (daisies, cosmos, sunflowers, yarrow, goldenrod), buckwheat, spearmint
Tachinid fly (Tachinidae family)	Cutworm, armyworm, tent caterpillar, gypsy moth, Japanese beetle, May beetle, squash bug	Carrot family (fennel, tansy, dill, bishop's weed, parsley), goldenrod, sweet clover, sweet alyssum, buckwheat, amaranth
Chalcid wasps (many families including Trichogrammatidae)	Spruce budworm, cotton bollworm, tomato hornworm, corn earworm, corn borer, codling moth	Maintain a diversity of plants including dill, caraway, hairy vetch, spearmint, buckwheat, yarrow, white clover, tansy, fennel, chervil

Table adapted from:

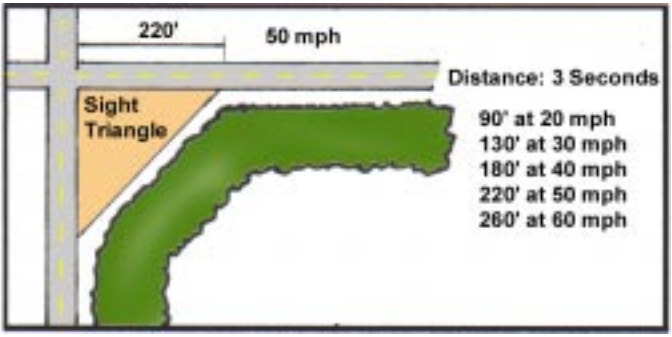
Defour, R. 2000. Farmscaping to enhance biological control. Appropriate Technology Transfer for Rural Areas (ATTRA). Fayetteville, AR.



5.4 Buffers and Road Ice

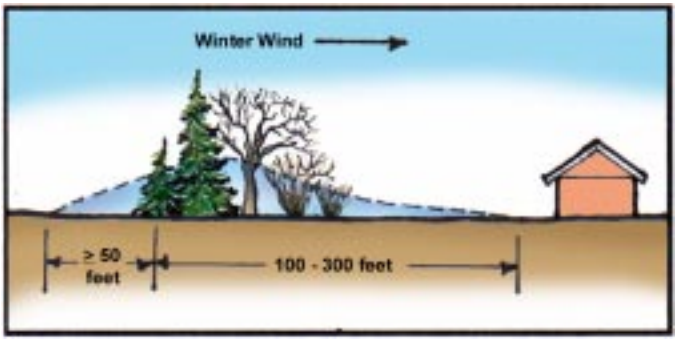
In northern climates where ice on roads is a concern, buffers should be set back from the road to allow sunlight to hit road surfaces for part of the day. Use the formula a=b/tan A to calculate the setback distance. [59]

Example: If tree is 35' tall and angle is 27 degrees then a = 68'.



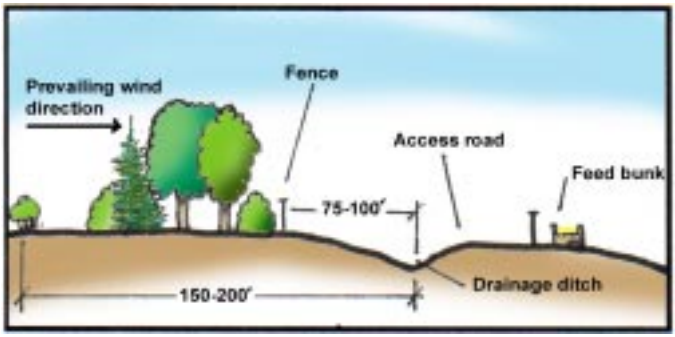
5.5 Buffers and Road Intersections

At intersections not controlled by stop signs, buffers should be designed to allow for views of oncoming traffic. 2 seconds for perception and reaction and 1 second for braking. Therefore, 3 seconds of viewing time is needed. Check with local agencies if there are specific regulations regarding intersection set backs. [59]



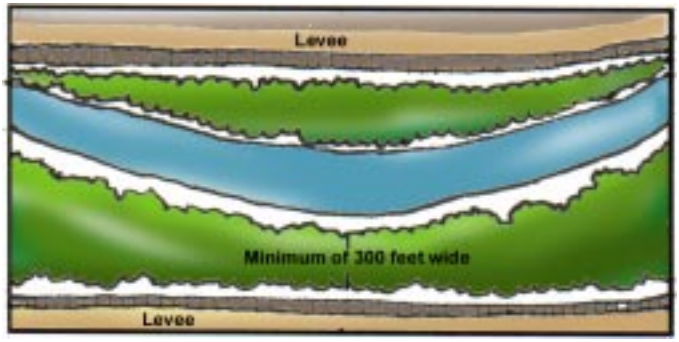
5.6 Managing Drifting Snow

To manage drifting snow, the windbreak should be positioned perpendicular to the prevailing winter winds. If the winds are vary in orientation, two windbreaks may be required. The ends of the windbreak should extend 45-100 feet beyond the area needing protection. Moderately dense windbreaks (50-65% porosity) provide the best protection. The windbreak should be set back 100-300 feet from the primary object or area needing protection. [176]



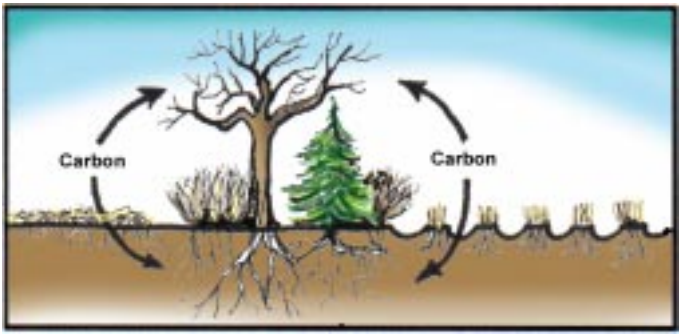
5.7 Windbreaks for Livestock

Windbreaks located on the north and west sides can protect livestock from winter winds and still allow summer winds to circulate in the feedlot or pasture. Windbreaks should be fenced to protect the windbreak from grazing, which can harm the plants and reduce the integrity of the windbreak. [39, 127]



5.8 Trees and Levees

Along large rivers with levees, woody corridors can reduce flood damage by protecting levees from breaching. Woody corridor widths should probably be a minimum of 300 feet wide, especially on outside meander bends where the erosive force is the greatest. Tree diameter should be managed to 6 inches or greater in diameter and gaps in corridor length should be avoided. [3, 40]



5.9 Carbon Sequestration

Sequestrating carbon in woody plant material is one method to reduce the effects of global warming due to industrialization. Carbon forms about half the dry weight of trees. When trees are combined with field management methods that increase soil carbon (i.e. no-till), significantly higher carbon storage can be achieved than just relying on field management techniques alone. [82, 102, 141, 164]

AESTHETICS AND VISUAL QUALITY

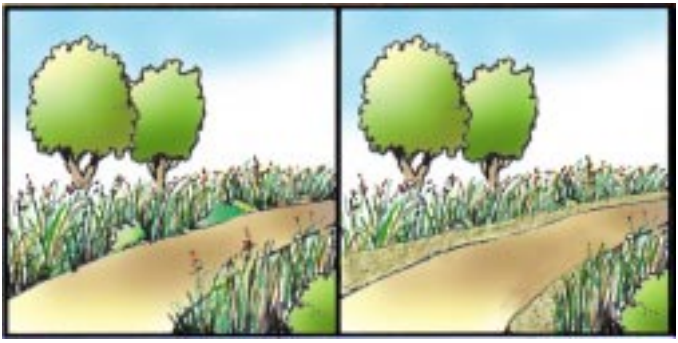
- *Enhance visual quality*
- *Control noise levels*
- *Control air contaminants and odor*

Potential Buffer Impacts on Ecological Function:

1. Create visual diversity
2. Screen undesirable views
3. Reduce noise
4. Filter air contaminants and odors

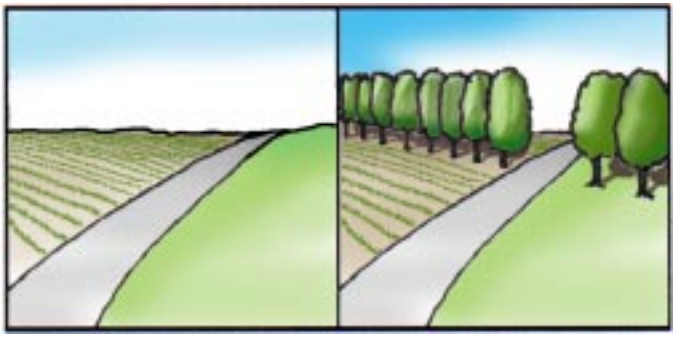
Aesthetics and Visual Quality Principles	Create visual diversity	Screen undesirable views	Reduce noise	Filter air contaminants and odor	
6.1 Use selective mowing to indicate stewardship.	■				
6.2 Buffers for visual diversity.	■				
6.3 Roadsides for visual diversity	■				
6.4 Buffers for visual screening.		■			
6.5 Buffers for noise reduction.			■		
6.6 Visual variety.	■				
6.7 Buffers for air contaminants.				■	
6.8 Design to be visually compatible.	■				

Other Principles Related to Aesthetics and Visual Quality	Create visual diversity	Screen undesirable views	Reduce noise	Filter air contaminants and odor	
1.3 Constructed wetlands for tile drainage.	■				
1.16 Waterbreaks	■				
2.5 Increase diversity in low interspersion areas.	■				
2.7 Edge diversity.	■				
2.21 Continuous stream corridors.	■				
2.23 Roadsides for wildlife and plants.	■				
2.26 Retain fence lines.	■				
3.2 Wind energy reduction.			■	■	
4.3 Remnants have value.	■	■			
4.4 Buffers and property values.	■				
5.8 Trees and levees.	■				



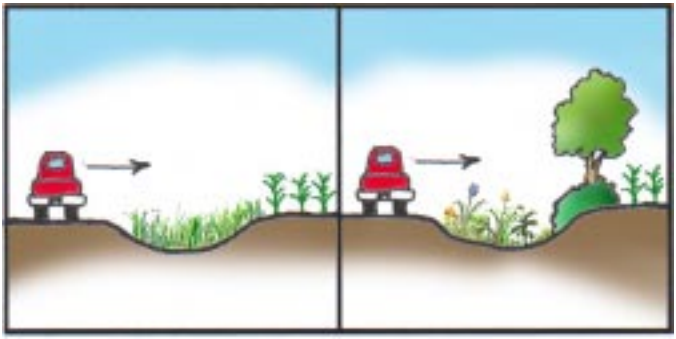
6.1 Use Selective Mowing To Indicate Stewardship

Herbaceous buffers usually need to be manage in a full vegetative state to achieve objectives but this can look unkempt to landowners. Selective mowing can be used to indicate stewardship without greatly minimizing the ecological functions. [60, 112, 113]



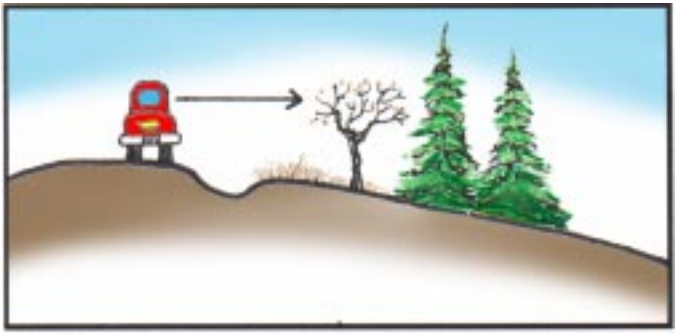
6.2 Buffers for Diversity

Research shows that the public often desires hedgerows and other woody buffers in the landscape for visual diversity, particularly in homogenous agricultural landscapes. [2, 22, 25, 60, 77, 166]



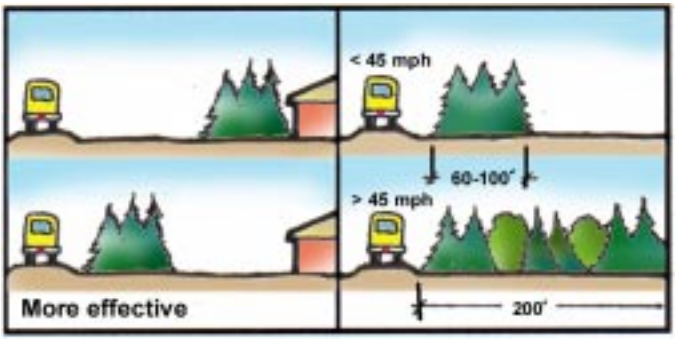
6.3 Roadsides for Visual Diversity

Roadsides can be managed to increase the visual quality of the landscape. Variety in plant color, texture, form, and height is more desirable than a monoculture. [2, 25, 66, 77, 166]



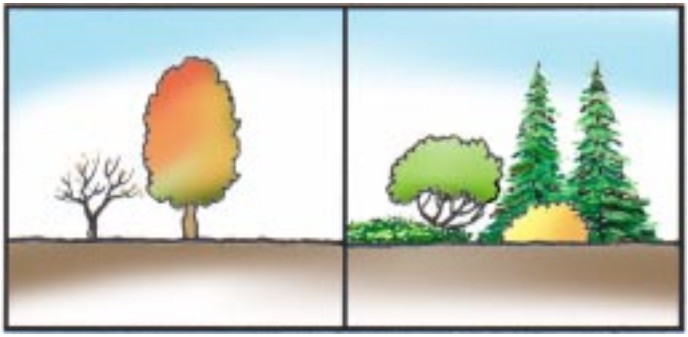
6.4 Buffers for Visual Screening

When designing buffers for visual screening, plants selected must be high and dense enough. Also seasons may need to be considered. Evergreens will provide dense screens year-round. [59, 77]



6.5 Buffers for Noise Reduction

The closer the buffer is to the noise source, the more effective it will be. When concerned about road noise, the faster the speed limit, the louder the noise. Buffers need to wider for faster speeds. For highway speeds, buffers need to be 200' wide and dense to reduce the noise level by 10 decibels (loudness cut in half). [24, 43, 61, 84]

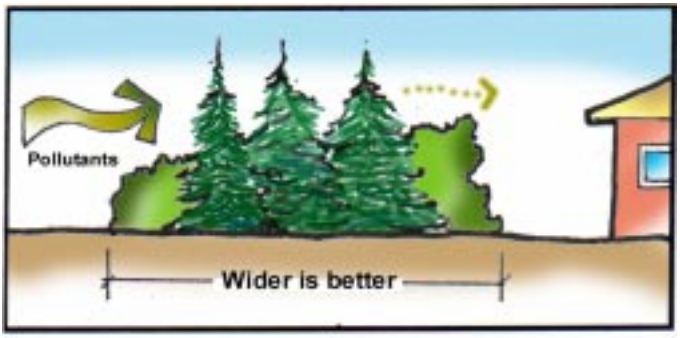


6.6 Visual Variety

Visual interest can be added to a buffer by selecting different plant species. Methods of adding visual variety include:

Seasonal Color
By Varying Height
Changing leaf texture
By Plant Forms

66, 77, 166



6.7 Buffers for Air Contaminants

Windbreaks may be used to mitigate air contaminants and ameliorate odors. Reducing wind speeds encourages dust and other aerosol deposition. Foliage, particularly dense evergreens, can intercept particles and may also act as sinks for chemical constituents of odorous pollution. [145, 156, 165]

Straight lines are compatible with this landscape.

Curved lines are compatible with this landscape.

6.8 Design to be Visually Compatible

When complementary to other buffer functions, buffers should be designed to fit in with the surrounding landscape. [60, 77, 166]

Outdoor Recreation

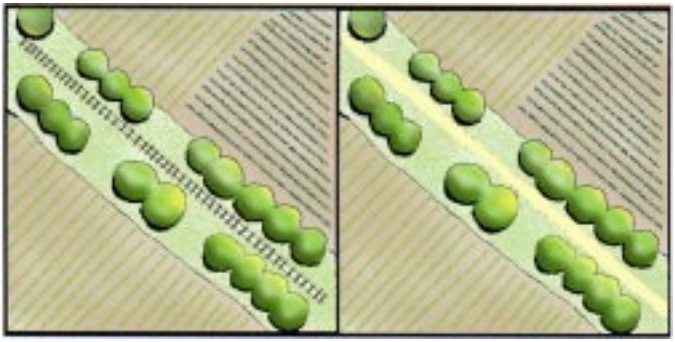
- *Promote wildlife viewing and hunting opportunities*
- *Provide buffers as recreational trails*

Potential Buffer Impacts on Ecological Function:

1. Increase habitat area
2. Restore connectivity between habitats
3. Provide a conduit for pedestrian movement

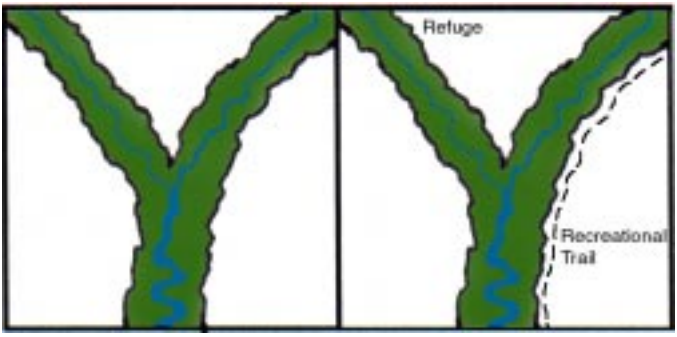
Outdoor Recreation Principles	Increase habitat area	Restore connectivity between habitats	Provide a conduit for pedestrian movement		
7.1 Abandoned rail lines as trails.			■		
7.2 Recreational trails along riparian corridors.		■	■		
7.3 Trail design and sensitive areas.	■		■		
7.4 Open versus enclosed trails.			■		
7.5 Multi-use trails			■		
7.6 Connected trails.		■	■		
7.7 Soil characteristics and trail recreation.			■		
7.8 Separation of rural and urban land-uses.		■	■		

Other Principles Related to Outdoor Recreation	Increase habitat area	Restore connectivity between habitats	Provide a conduit for pedestrian movement		
2.0 All species and habitat principles					
4.7 Economic impact of trails.					
5.4 Buffers and road ice.					
5.5 Buffers and road intersections.					
5.6 Managing drifting snow.					
6.1 Use selective mowing to indicate stewardship.					
6.2 Buffers for visual diversity.					
6.4 Buffers for visual screening.					
6.5 Buffers for noise reduction.					
6.6 Visual variety.					
6.8 Design to be visually compatible.					



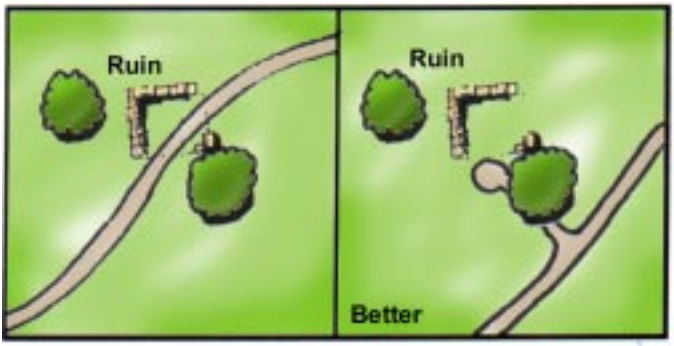
7.1 Abandoned Rail Lines As Trails

Abandoned railroad lines can be easily converted to multi-use recreational trails. Research has shown that rail trails can bring in significant economic benefits to areas where the trails are located. [110, 144]



7.2 Recreational Trails Along Riparian Corridors

Riparian corridors can be great locations for recreational trails. To minimize the negative impacts of recreation on the riparian area, locate the trail to the outside of the riparian areas and leave some areas as refuges without trails. [98, 99, 100, 144]



7.3 Trail Design and Sensitive Areas

Ecologically or culturally sensitive areas should be protected by designing spur trails off of primary trails rather than routing the primary trail through or along a sensitive area. [98, 99, 144]

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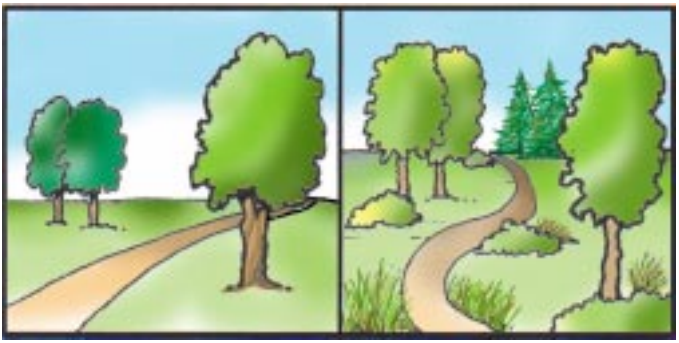
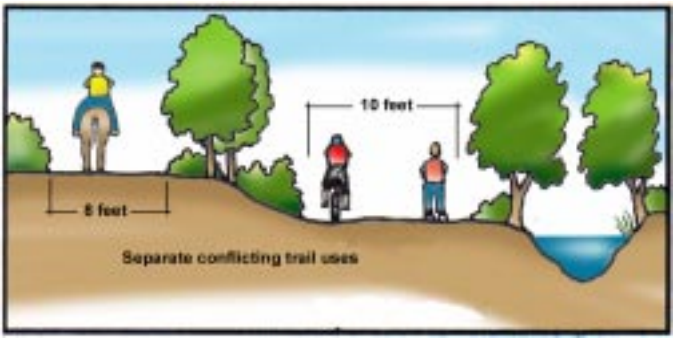


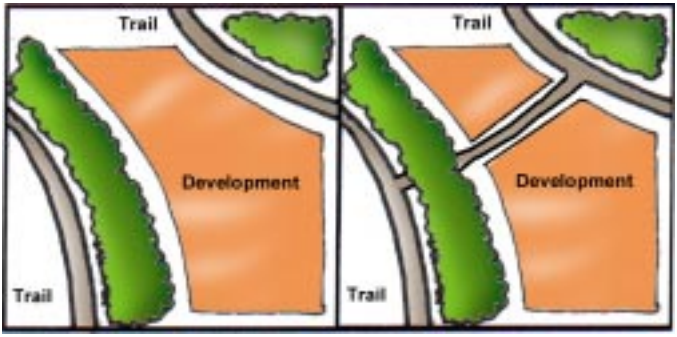
7.4 Open Versus Enclosed Trails

Trails that pass through open areas with few trees or distinct features are less preferred. People generally appreciate trails that have a mixture of open and enclosed areas. Trails that create a sense of mystery through a curvy path alignment also provide more interest for pedestrians. [77]



7.5 Multi-use Trails

Trails can be designed to safely accommodate multiple uses and multiple modes of travel. Trails that serve multiple uses significantly increase public support for the trail system. Trail design standards are available that provide guidance on alignment, surface materials, width, and trail profile or slope. [59, 144]



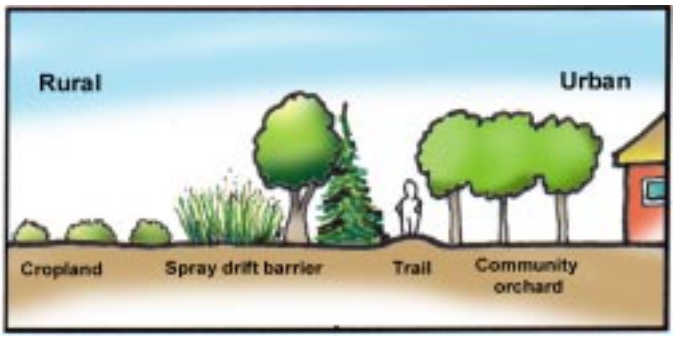
7.6 Connected Trails

A system of connected trails offers a more pleasant and continuous recreational experience than unconnected trails. Trail design should also provide safety by making key connections across barriers like roads, fences, or railroads. When trails are planned in advance of development, expensive retrofits like trail underpasses or overpasses can be avoided. [76, 144]

	Level of Vulnerability to Recreation		
Soil Property	**Low**	**Medium**	**High**
Texture	Medium	Coarse	Fine
Organic Content	Moderate	Low	High
Soil Moisture	Moderate	Low	High
Fertility	Moderate	High	Low
Soil Depth	None	Deep	Shallow

7.7 Soil Characteristics and Trail Recreation

Depending on inherent soil characteristics, trail recreation may negatively impact soil and water quality. The vulnerability of soils to recreational impacts depends on number of factors and can be avoided or mitigated through proper design. General relationships are shown in the above table. [144]



7.8 Separation of Rural and Urban Land-Uses

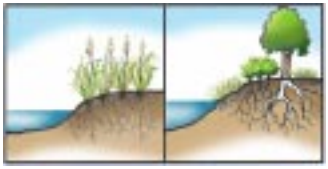
The rural-urban interface is often a zone of conflict due to conflicting land uses and management techniques. Buffers can serve as a physical feature separating these land uses and can simultaneously achieve multiple objectives such as a spray drift barrier and recreational trail for rural and urban residents. The key is to design these buffers with input from all potential stakeholders. [96, 137]

Using Flood Protection To Achieve Multiple Benefits

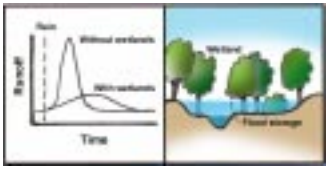
Lincoln, Nebraska

Some of the principles illustrated by this case study:

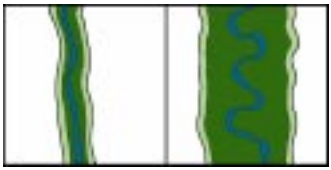
1.13 Roots and Streambanks



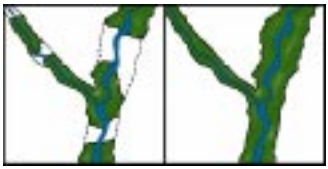
1.15 Flood Reduction and Sediment Control



2.19 Wider Corridors Are Better Than Narrow Corridors.

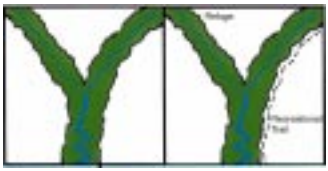


2.21 Continuous Stream Corridors.



4.7 Economic Impact of Trails

7.2 Recreational Trails Along Riparian Corridors



Case Study: Wilderness Park

***Fig.11**: Wilderness Park along Salt Creek.*

Due to frequent flooding along Salt Creek near Lincoln, NE, the riparian woodlands have remain essentially intact. Comprehensive plans as early as 1962 recommended a park along Salt Creek and in 1966, the City of Lincoln, Lancaster County, and Salt Valley Watershed District joined in to purchase what is now Wilderness Park. The park was initially established for flood protection and recreational activities.

The park currently consists of 1,457 acres of floodplain with a mosaic of riparian woodlands, remnant grasslands, and old agricultural fields. The park extends approximately seven miles and averages 1320 feet (about ¼ mile) in width. This wide corridor is critical for providing adequate flood storage and to allow natural meandering of Salt Creek.

The primary uses of the Park include:

- Provide low cost flood protection
- Provide public access to a natural area
- Provide education opportunities regarding the interaction of natural populations with urban development
- Provide a historical, cultural, and archeological record of the area
- Establish a model for greenspace areas that could be replicated in other parts of the County

The Comprehensive Plan calls for extending Wilderness Park an additional 7 miles to the south, adding 2,500 acres to the park, costing an estimated $5 million to acquire and $108,000 a year to maintain. Although planners would like to extend the Park to the north, land prices and existing urban development require prioritizing protection efforts on the southern, less developed region.

The Federal Emergency Management Agency (FEMA) has recognized this approach as a viable way for communities to reduce flood damage and has contributed $1.1 million to purchase conservation easements in the Wilderness Park area. Through FEMA's Hazard Mitigation Grant Program, FEMA funds 75% of the approved projects with the City and County providing a 25% match. In addition, the Nebraska Environmental Trust Fund has also recommended that $500,000 in lottery proceeds be used over three years to purchase additional easements in the area.

Eventually, Wilderness Park may become part of the proposed Salt Valley Heritage Greenway system, a continuous open space loop around Lincoln providing a connection with both rural and urban communities. It would include parks and open space, trails, active and resource-based recreation, riparian corridors, floodplains, saline and freshwater wetlands, agricultural land, abandoned rail lines, and transportation corridors. This area may eventually connect a network of trails that would extend into northern Kansas. This proposed system illustrates the importance of integrating the buffer system at the regional scale.

***Fig.12**: The proposed Salt Valley Heritage Greenway system.*

Although Wilderness Park is a valued resource in the community, the park does face continued threats. The park is currently crossed by only three roads, maintaining a strong sense of connectivity in the riparian buffer. Transportation plans have proposed to extend a new road crossing through the park which could greatly fragment the corridor, reducing its role as a conduit for movement of wildlife and people.

In addition, increasing impervious cover due to urban development is contributing to high peak flows and greater streambank erosion resulting in streambank instability. This highlights the critical need to consider buffers in a watershed context. These conservation approaches can be easily over loaded if the rest of the watershed is not managed in appropriate manner.

For more information:

Parks and Recreation Department
2740 A Street
Lincoln, NE 68502
(402) 441-7847
http://www.ci.lincoln.ne.us/city/index.htm

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***Fig.13**: Wilderness Park along Salt Creek.*

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GLOSSARY

Buffer/Corridor: A linear patch that differs from its surroundings.

Dispersal: A one-way movement of either an animal or plant species.

Heterogeneous: Consisting of dissimilar elements.

Interspersion: The level of integration of plant communities both natural and introduced.

Matrix: The background component of landscapes within which patches and corridors exist.

Metapopulation: Wildlife populations that are distributed as spatially separated populations linked by dispersal.

Patch: A plant and animal community that is surrounded by areas with different community structure.