Chapter 6: Windbreaks

Chapter Highlights

- Windbreaks reduce wind speed, control soil erosion, protect livestock and crops, improve energy efficiency, and enhance biodiversity. They can also provide wildlife habitat, sequester carbon, purify air, reduce noise, and make aesthetic improvements to the landscape.
- Effective windbreaks consider height, density, orientation, and species selection to optimize wind reduction and minimize turbulence. Proper spacing between trees and rows influences windbreak efficiency, with multiple-row designs offering better protection and longevity.
- Proper windbreak design is crucial to avoid unintended impacts like increased turbulence, snow drifting in unwanted areas, or reduced protection due to gaps, which could worsen conditions rather than improve them.

Agricultural practices benefiting from properly applied windbreaks include:

- *Crop production*
- *Soil conservation*
- *Livestock and dairy cattle husbandry*
- *Livestock confinement facilities.*
- *Nut, fruit, and berry crops*

Crops that can be produced from actively managed windbreaks include:

- *Nuts, fruits, berries*
- *Timber, fencepost, firewood*
- *Christmas trees*
- *Boughs, cones, wreaths*
- *Landscape plants*
- *Shade-tolerant plants such as those grown in the forest farming practice*
- *Lease hunting opportunities when managed for wildlife benefits*



This chapter is intended to help you design and manage the interactive agroforestry practice of windbreaks. Properly applied on a landscape, a windbreak can enhance and diversify farm income opportunities, improve the environment and create wildlife habitat. By developing an understanding of the interactions between the windbreak (trees, shrubs and grasses) and the adjacent land area, its layout can be most effective at meeting the goals for which it is, or has been, established. By understanding the needs of each of the windbreak's component parts, the windbreak can be managed to best maintain its effectiveness over time, and also sustain its contributions to the farm or ranch. Read more about current funding opportunities in an addendum to this publication available at centerforagroforestry.org/training-manual.

Windbreaks Defined

A windbreak is any barrier (natural or artificial) that reduces troublesome winds by creating a wind shadow to the leeward (down-wind) side. Its major function is to reduce the velocity of the wind. A windbreak must be 2.5 feet or higher to have a significant effect. Many kinds of materials can be used for a windbreak, including trees, shrubs, tall perennial or annual plants (e.g., switchgrass or sunflowers) that will attain a sufficient height to create the desired wind shadow.





Seven Windbreak Structural Elements that Determine Effectiveness

1. *Height*
2. *Density*
3. *Orientation*
4. *Length*
5. *Width*
6. *Continuity/ uniformity*
7. *Cross-sectional shape*

The windbreak or shelterbelt practice, uses intensive management for growing trees, shrubs and/or grasses adjacent to other agricultural practices, and consists of one or more rows of closely spaced trees and/or shrubs planted at right angles to the prevailing winds. A windbreak becomes important to the agricultural system by enhancing production, or conservation, as it modifies air movement and wind speeds resulting in microclimatic changes. The terms windbreak and shelterbelt can be used interchangeably.

How Windbreaks Function

Windbreak height. Height (referred to as 'H') is the most important factor determining the downwind area of protection. The windbreak 'H' is the height of the tallest row of trees in the windbreak. The windbreak will reduce wind speed for 2 to 5 times the height of the wind- break (2H to 5H) on the upwind side and up to 30H on the downwind side of the barrier. The area protected is a direct result of the height and density.

Windbreak density. Density is the ratio of the solid portion of the barrier to the total area of the barrier. Wind flows through the open portions of a windbreak, thus the more solid the windbreak, the less wind passes through. By adjusting windbreak density, different wind flow patterns and areas of protection are established.

Density level is manipulated by choice of plant materials (e.g., deciduous vs. conifer); and plant arrangement. By combining low growing shrubs with medium and tall deciduous trees, dense plant material is provided at three levels (low, middle and upper) of the windbreak during the growing season. However, during the winter, the density would decrease due to the loss of foliage. Consequently, a conifer component would be desirable for year-round protection.

- **Dense (60-80%)** = *maximum wind reduction but short wind shadow*
- **Moderately dense (40-60%)** = *less wind reduction but longer wind shadow*
- **Under 40%** = *effective for snow distribution across a field*

The term windbreak porosity may also be used to characterize this structural element. The percentage of porosity is the amount of open spaces in the windbreak when viewed perpendicular to the windbreak. In other words, porosity is the inverse of density, i.e., a 60 percent

Deciduous 25-35% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	5	6.5	8	8.5	10
% of open wind speed	50%	65%	80%	85%	100%

Conifer 40-60% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	3	5	6	7.5	9.5
% of open wind speed	30%	50%	60%	75%	95%

Multi-Row 60-80% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	2.5	3.5	6.5	8.5	9.5
% of open wind speed	25%	35%	65%	85%	95%

Solid Fence 100% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	2.5	7	9	9.5	10
% of open wind speed	25%	70%	90%	95%	100%

Fig. 1. Wind speed reduction to the lee of windbreaks with different densities.

dense windbreak would be 40 percent porous.

The degree of density will impact the extent of the area being protected and the magnitude of protection as shown in Figure 1. A solid fence (100% density) provides maximum wind reduction, but the area of wind reduction is shorter than with a dense tree windbreak. The dense windbreak (60-80%) provides a greater area of protection, and the magnitude of wind reduction is as good as the solid structural fence or wall. For the moderately dense wind- break (40-60%), the magnitude of wind reduction is somewhat less but the wind shadow is at its maximum. Once the density drops below 40%, the effectiveness of the windbreak begins to decline. However, the 25-35% density level is very effective for even distribution of snow across a field for moisture management. This density level is not as good for stopping wind erosion.

Windbreak orientation. Windbreaks are most effective when oriented at right angles to prevailing or troublesome winds, (Fig. 2 a, b, c, below). The best orientation for each windbreak depends on the objectives for the windbreak. A key point to remember is that although the troublesome wind may occur primarily from one direction, it rarely blows exclusively from that direction. As the wind changes direction and is no longer blowing directly against the windbreak, the protected area decreases.

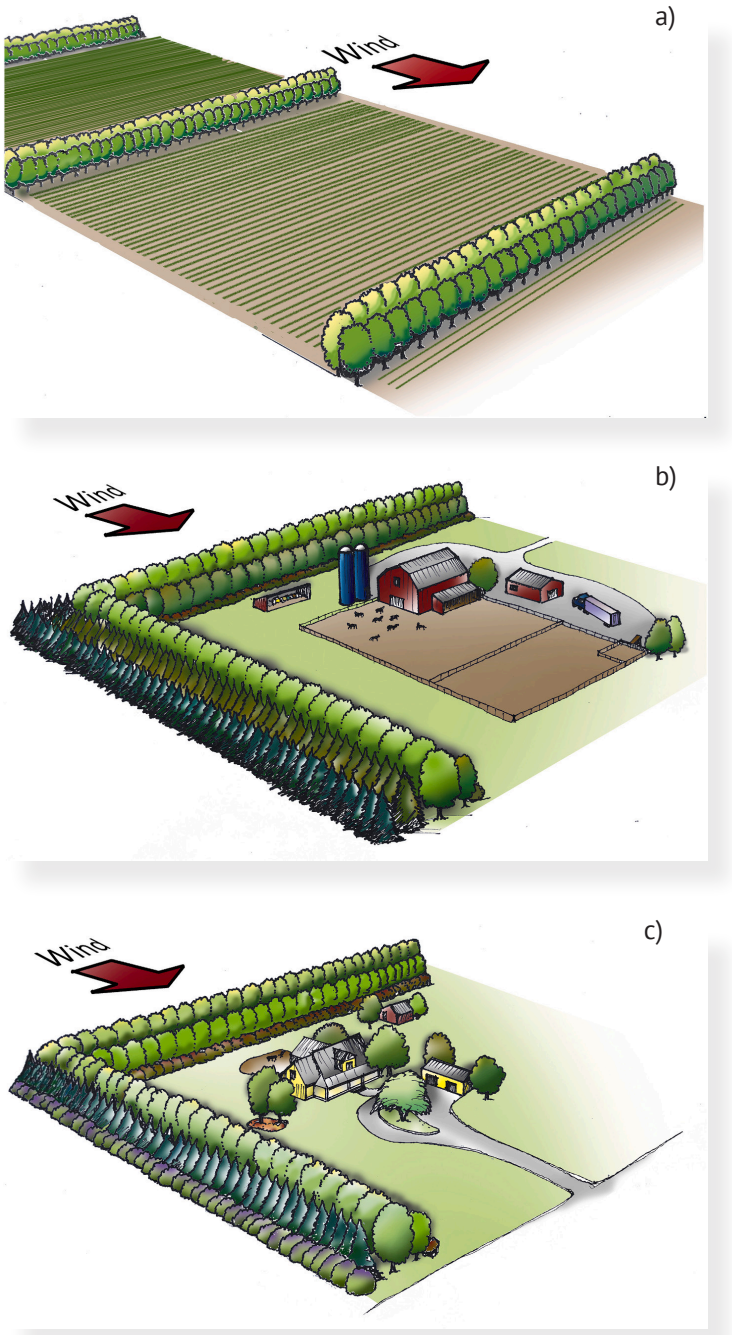


Fig. 2. Conceptual diagram of: a) field windbreak, b) livestock windbreak, c) farmstead windbreak (Smith et al., 2021)

Advantages of Windbreaks

- *Enhance crop yield*
- *Protect soil from wind erosion*
- *Shelter livestock and crops*
- *Capture water runoff and nutrients*
- *Improve irrigation efficiency*
- *Filter and reduce dust*
- *Help control odors*
- *Screen unsightly areas*
- *Provide wildlife travel corridors and habitat*
- *Protect structures (homes, outbuildings, roads)*
- *Reduce noise*
- *Improve aesthetics*

Disadvantages of Windbreaks

- *Require more intensive management*
- *Need specialized equipment for tree/ shrub management*
- *Remove land from annual crop production*
- *Financial returns increase gradually as a windbreak grows*
- *May harbor harmful crop pests, e.g., insects & weeds*

Windbreak length. Although the height of the windbreak determines the extent of the protected area downwind, the length of a windbreak determines the amount of total area receiving protection. For maximum efficiency, the uninterrupted length of a windbreak should exceed the height by at least 10:1 (i.e., a windbreak 30 feet tall needs to be at least 300 feet long). The ratio reduces the influence of end-turbulence on the total protected area.

Windbreak width. The width primarily serves as a means to manipulate the desired density of the windbreak. The number of rows, the distance between trees, and species composition are factors controlling windbreak density. Increasing the number of rows or decreasing the distance between trees increases density and provides a more solid barrier to the wind. A wider windbreak can also increase the value of the windbreak for wildlife and offers opportunities to produce products.

Windbreak continuity. Continuity influences efficiency. Gaps in a windbreak become funnels that concentrate wind flow, creating areas on the downwind side of the gap in which wind speeds often exceed open field wind velocities. Gaps will decrease the windbreak's effectiveness. Access lanes through a windbreak should be avoided or minimized.

Windbreak cross-sectional shape. Some windbreak guides call for a "hip-roof shape" to assist in "lifting" the wind. However, the cross- sectional shape of windbreaks with equal densities has minimal influence on wind velocities within 10H of the leeward side of a barrier. Beyond 10H, straight sides provide slightly more protection than slanted sides because more wind passes through the trees and extends the protected area farther to the leeward.

Windbreak Benefits

Windbreaks offer a variety of potential environmental and financial benefits to a farm or ranch enterprise through protection of crops and livestock. The rural community also benefits from improved air quality through wind speed reductions and the physical capture of airborne particulates including dust, smoke, pesticide droplets and odors. Windbreaks also provide aesthetic diversity by adding trees in an agricultural landscape and enhance wildlife habitats and corridors through the addition of tree, shrub and herbaceous cover.

Benefits for the soil

Windbreaks have been widely recognized as a key tool to reduce wind erosion. When wind speed is reduced, the wind erosion process cannot start. Wind erosion can rob land of precious topsoil containing nutrients and organic matter. This loss can lead to reduced productivity and the need to add more nutrients. Wind erosion potential is the greatest when fields are very wide and the soil is bare and smooth. Windbreaks combined with other wind erosion control measures (e.g., reduced tillage, herbaceous wind barriers) create a conservation approach to tolerating wide weather extremes.

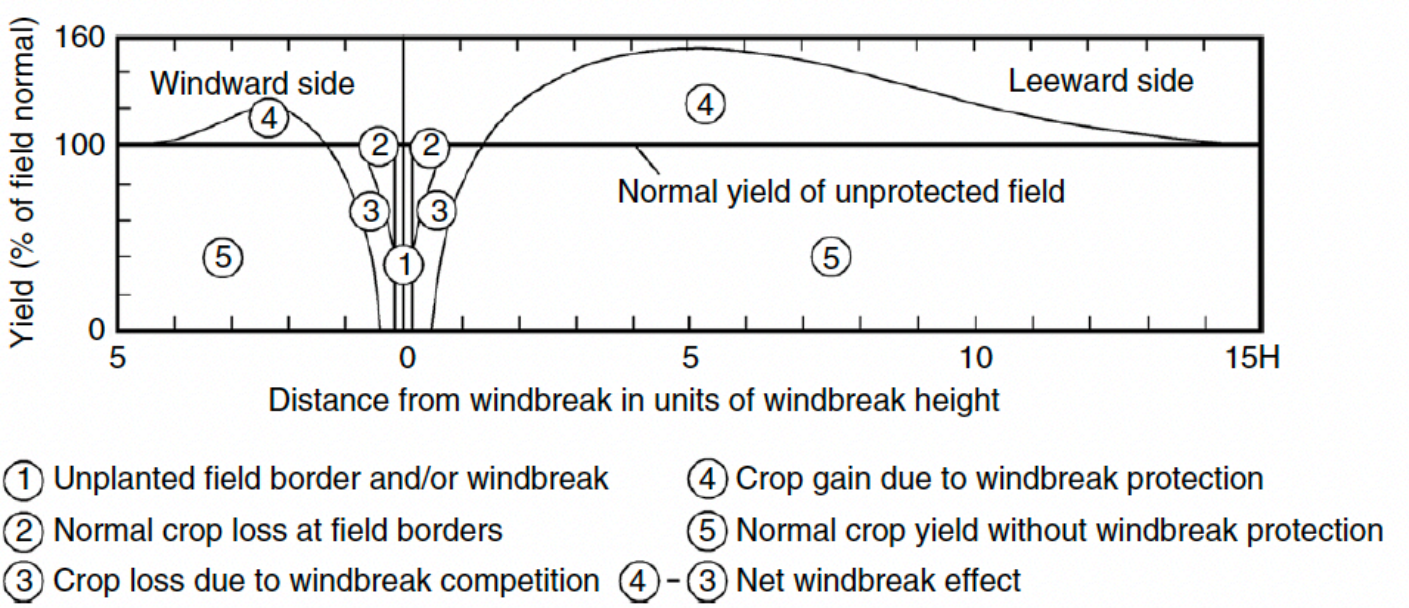


Figure 3. The generalized case for crop yield responses for a field windbreak in the Great Plains. (Brandle et al., 2021)

Benefits for crops

Windbreaks improve crop production and quality by modifying the micro-climate and reducing wind erosion. They protect crops from insect pests by reduced crop visibility, dilution of pest hosts due to plant diversity, interference with pest movement, creation of environments less favorable to pests and more favorable to beneficial insects. They can be designed to manage snow drifting to maximize use of the moisture for crops. Windbreaks improve irrigation efficiency by reducing evaporation losses; and improve water quality through interception of sediment and interception, sequestration and decomposition of agricultural chemicals in the tree, shrub and herbaceous rhizosphere.

When field windbreaks are suggested to land stewards, they often have a mental image of crop reduction and/or loss adjacent to the windbreak and from the space occupied by the windbreak. What is often not recognized is the potential for increased crop quality and quantity on the leeward (downwind) side of the windbreak. Many years of field research have shown there is a yield advantage for many crops when protected by a windbreak. This yield increase generally occurs from 1.5/2H to 10-12H on the leeward side of the windbreak (Fig. 3). The amount of yield increase will vary from year to year due to different weather conditions. There will also be some variation due to soils and the types of trees used in the windbreak (i.e., less competitive trees result in greater gains). The yield advantage is normally more than enough to offset the decrease in yield immediately

Crop Windbreaks: Weighted Average Crop Yield Increase			
Corn	**12%**	**Soybeans**	**13%**
Barley	**25%**	**Winter Wheat**	**23%**
Hay	**20%**	**Spring Wheat**	**8%**



This field windbreak is designed to provide year-round protection by incorporating cedar and pine outer rows with an interior row of deciduous shrubs.

adjacent to the windbreak and the land occupied by the windbreak. Some land stewards will plant a deep rooted crop such as alfalfa adjacent to the windbreak in the area most impacted by competition and are able to gain good quality forage.

Benefits to orchards and vegetable crops

In addition to the traditional commodity crops, windbreaks are also used to protect a variety of horticultural crops including many fruit and vegetable crops. Some of the key benefits of protecting these types of crops include: improved crop quality from reduced bruising, better pollination from insects due to less wind, and early maturing of the crops resulting in possible marketing advantages. Windbreaks around orchards are also being examined for their use in preventing off-site drifting of pesticides. Many orchards and other farms are being engulfed by housing developments. Windbreaks can help buffer potential land-use conflicts.

Benefits to livestock

Windbreaks provide valuable protection to livestock especially for young animals and in areas with cold northerly winds during winter and early spring. Reducing the wind impacts lowers animal stress and improves general health resulting in better livestock production by increasing feed efficiency and weight gains, improving survival of newborns and increasing milk production. Windbreaks can also provide living screens to separate incompatible uses (i.e., livestock facilities from suburban residences).

Windbreak Design

Designing windbreaks requires the planner to be able to manipulate the different structural components of a windbreak in order to achieve the desired effect. Climatic and physical effects such as wind speed, apparent air temperature, snow deposition and evapotranspiration are modified as a result of the structural characteristics of the windbreak. Ask yourself: what needs to be protected? Crops/orchards? Soil? Livestock and/or livestock buildings?

Step 1. Determining the windbreak purpose

As noted previously, a windbreak can have a variety of purposes ranging from crop protection to snow management. The design of the windbreak is dependent upon the purpose(s) desired. To determine the purpose(s) requires understanding the desired objectives of the land steward and the physical site characteristics.

The first step in design is to interview the land stewards to ascertain their objectives or purposes for the windbreak. A questioning strategy can be effective such as:

Crops

- *Have you had any wind erosion from your fields? If so, when did it occur?*
- *From which direction(s) does the wind cause the most problem(s)?*
- *Are you using other wind erosion control practices, e.g., reduced tillage?*
- *Have you had any crop damage or loss from the wind or blowing soil?*
- *When did it occur?*
- *From which direction(s) does the wind cause the most problem(s)?*
- *What crops are you growing that may be wind sensitive?*
- *Are you growing crops that need pollination?*

Livestock

- *When do your livestock need the most wind protection?*
- *What livestock pastures, lots or structures need wind protection?*
- *Do we need to be concerned with summer air movement in the livestock area?*
- *Which access roads need to be kept clear of snow?*
- *Is there a drainage issue associated with rain or snowmelt runoff?*

Step 2. Site evaluation

The next step is to evaluate the site conditions that may affect windbreak design and application. Use a conservation plan map or photo to identify fields in need of protection, existing windbreaks, soil problems, utilities, direction of prevailing erosive winds, property lines, roads and access lanes. (Fig. 4)

- *Identify all areas needing protection based on the troublesome wind direction(s).*

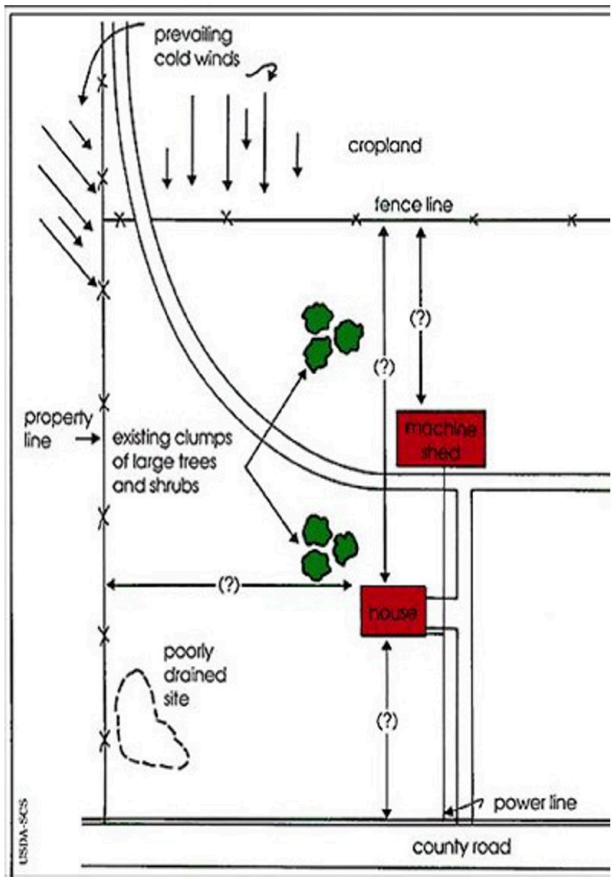


Figure 4. Area sketch for site evaluation.

- *Inventory the soils. Begin a starter list of species adapted to the soils.*
- *Observe the topography to determine any drainage concerns either into or away from the windbreak (especially snowmelt and feedlot runoff)*
- *Locate property lines, overhead and underground utilities (electric, telephone, gas, and/ or sewer), and existing trees or shrubs which may be within or adjacent to the proposed windbreak.*
- *Identify any access roads or lanes that could cause gaps in the windbreak.*
- *Locate the windbreak to avoid obstructing the winter sun, or oncoming traffic near driveways. Identify protection needs for the windbreak, such as fencing to keep out livestock.*
- *Observe any existing plant species which may be alternate hosts for pathogens, e.g., cedar-apple rust.*
- *Inventory existing wildlife habitat and wildlife species in the area so the windbreak may complement.*

Step 3. Design considerations for different windbreaks

Windbreak design tips for crop fields

- *For crop protection/production and/or uniform snow distribution, windbreak-to-windbreak intervals should be 15 to 20H. For crops highly susceptible to damage from wind or small amounts of wind-blown soil during some portion of the growing season, a spacing interval of 6-10H provides a high degree of protection.*
- *For erosion control purposes, NRCS uses a rule of thumb of "no erosion out to 10H leeward" – leading to a windbreak-to-windbreak interval of 10H plus the distance protected by the agronomic system (i.e., standing crop, crop residues, cropping pattern, ridging) being used.*
- *Different design densities and heights result in different snow drift patterns. For example, if the land steward wants to spread snow evenly across a field to improve soil moisture in a crop field, the windbreak design density should range from 25 to 35 percent. This would be roughly equivalent to a single row of deciduous trees without leaves at a wide spacing (15 to 20 feet). If soil erosion is a potential problem during the time the windbreak is at this density level, additional conservation measures will be needed.*

Plan for:

- ***40-60% density for crop & soil protection***
- ***25-35% density for snow distribution***

Windbreak design tips for livestock

- *Greatest wind protection occurs from 2H to 5H leeward of the tallest tree row.*
- *For wind and snow protection, the most windward row needs to be 100 to 200 feet from the windward edge of the primary protection area.*
- *Allow room for snow deposition outside of the feeding area. Care must also be taken to accommodate the drainage both from the clean water runoff from the windbreak (i.e. snowmelt) and drainage from the livestock feeding area. Effluent from the feeding area can harm and sometimes kill trees and shrubs.*

- *Critical temperatures for beef cattle are determined in part by the condition of the coat. Below the critical temperature, livestock must expend more energy to keep warm.*

Livestock Critical Temperatures *adapted from D.R. Ames, Kansas State University*	
Coat Description	**Critical Temperature**
Summer coat or wet	59°F
Fall coat	45°F
Winter coat	32°F
Heavy winter coat	18°F

General design considerations

- *Avoid creating gaps with access roads cut through a windbreak. Wind flow increases through gaps decreasing windbreak effectiveness. Where needed, design the opening at an angle to prevailing winds. Lanes or roads through single-row barriers should be avoided; where necessary, locate them 100 to 500 feet from the ends of the windbreak (Fig.5).*
- *Locate new rows of trees 50 feet from existing trees.*
- *Stay away from subsurface drain fields and overhead utilities.*
- *Avoid locating windbreaks within 200 feet of road intersections to prevent poor driver visibility.*

Selecting tree and shrub Species

All species of trees and shrubs do not grow at the same rate nor do they grow to the same mature height. Likewise, adapted species vary in their growth on different soils within a geographical area. The amount of available soil moisture during the growing season and soil aeration are two important factors affecting tree and shrub growth. These factors are largely determined by soil texture, soil depth and climate

Windbreak Plant Materials

- Select plants adapted to climate and soils.
- Select plants to meet objectives, including: foliage density characteristics, height potential, and/or wildlife needs.

Conservation tree and shrub suitability groups have been developed as a guide for selecting species best suited to different kinds of soils, and climate, predicting height growth at 20 years, and measuring effectiveness. These guides should be available in the NRCS Field Office Technical Guide. Information about different plants can also be obtained from the USDA plants database.

In addition to selecting plants adapted to the climate and soil, plants need to be selected that have the greatest potential for meeting land steward objectives. The primary objective is to select plants that will provide the desired level of wind protection in a reasonable length

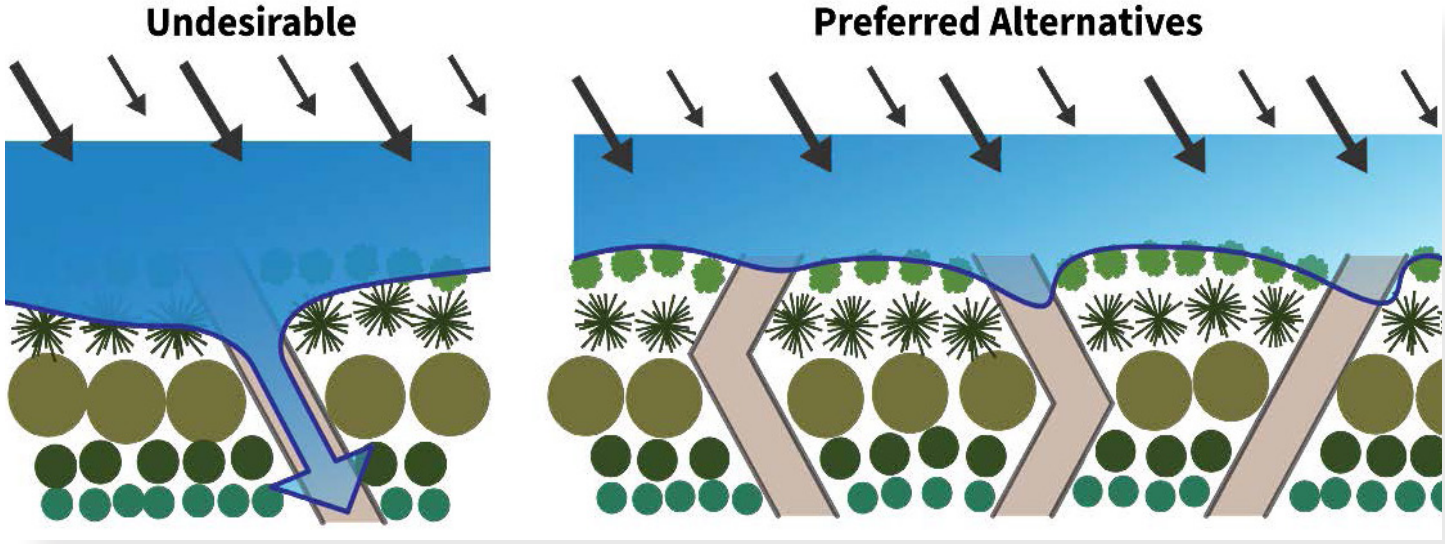


Figure 5. Windbreak designs for access lands or roads. (Kafer & Straight, 2022)

of time (within 10 years). This means selecting species that will give the appropriate level of density and optimum height for the site. For example, conifers need to be considered if optimum year round wind protection is desired. If wildlife is desired, select appropriate plants for the desired animals or birds.

Productive Windbreaks

For most of the other agroforestry practices, e.g., Alley Cropping and Silvopasture, a marketable product is typically produced from the woody component. Windbreaks have historically been a conservation practice providing benefits to the adjacent area by reducing wind impacts. The trees and shrubs in a windbreak have rarely been managed to sell a product. In older windbreaks planted in the 1930's and 1940's, plants were chosen that could provide fruit for home consumption and trees were cut for use as fence posts and rough lumber on the farm. The concept of producing usable products from windbreaks and other conservation practices has recently been revived and promoted in Productive Conservation: Growing Specialty Forest Products in Agroforestry Plantings.

For example, nut and fruit producing plants could be incorporated into a windbreak design with the intent of harvesting the fruits/nuts as a product. The harvesting would not impact the other benefits of the windbreak. Some commonly harvested fruits include chokecherry, highbush cranberry, sand cherry, currants, Cornelian-cherry dogwood, jostaberry, Nanking cherry, chokeberry, buffaloberry, pawpaw, persimmon, and many others. All are harvested for home consumption, but many are also gathered for commercial use as fresh fruit, jams, jellies, syrups, juices, concentrates, confections and wines.

A second possible enterprise could be decorative woody florals. Any woody plant species that has a colorful or unusually shaped stem, bud, flower, fruit or even leaf can become a decorative floral product. Some plant examples include stems from red and yellow-stemmed dogwoods; and curly, pussy, flame and basket willows. Even though the stems of these plants will be harvested, most of them will resprout from the roots restoring their value as part of the windbreak.

With any of these concepts, careful advanced planning is needed. Some unique challenges include understanding available markets, timing of harvest, perishability of the product, available labor, wildlife pressure, year-to-year production, etc. Once these issues have been resolved, thought is needed to decide how to incorporate the plants into the windbreak design. If the plants that will be harvested are primarily shrubs, the design can be fairly easy since shrubs typically are included in the outer or inner rows which will make access easier. Growing specialty forest products in windbreaks can provide supplemental income while at the same time improving the environment. Another advantage is that the windbreak will receive more management care and could result in a longer lasting planting. Success will only occur if the grower is a skilled manager and an effective marketer.

Windbreak Site Preparation, Planting and Maintenance

Site preparation

Site preparation is an important first step to ensure successful survival of the trees and shrubs in the windbreak. The goal is to maximize the amount of moisture at the site and to minimize the potential for weed competition. The type of site preparation used depends on the soil and existing vegetation at the site. With sandy soils, care must be given to avoid wind erosion problems. On sloping sites, precautions must be taken to prevent water erosion. Site preparation can be accomplished either mechanically (e.g., tillage equipment including chisel plow, disc, rototiller, or scalper), chemically (pre and/or post emergent herbicides) or a combination of both.

Site preparation

- *Maximize moisture*
- *Minimize competition*
- *Match the site*
- *Be timely*
- *Care for plants*
- *Plant at correct depth*

Planting

Tree planting methods include using either a tree planting machine or hand planting tools. For both methods, some key techniques need to be followed:

- *Do not plant on hot, windy days.*
- *Prevent roots from drying out.*
- *Do not plant when the temperature is freezing or below.*

- *Plant seedlings in a vertical position with root collar 1" below soil surface.*
- *Prepare a trench or hole deep and wide enough to permit roots to spread out naturally; avoid "J-rooting" - prune roots as needed to prevent J roots.*
- *Pack soil firmly around roots to eliminate air pockets.*

In arid areas where trees are difficult to grow shrubs or tall native grasses may be used to provide crop protection, to control wind erosion, and to capture snow for crop production.

Maintenance

The goal is to maintain the health and vigor of individual trees and shrubs while maintaining the overall structure of the windbreak as an effective wind barrier. With proper care, a windbreak will serve a long life of protection.

Windbreak Maintenance

- *Weed/grass control for the first 3 to 5 years with optional cover crop between rows*
- *Use supplemental water to ensure early survival and development*
- *Replant to fill gaps*
- *Protect from animals and pests*
- *Use corrective thinning and pruning*
- *Do not fertilize (cost prohibitive)*

Weed/grass control: Weeds need to be minimized usually for the first three to five years in a band about three to four feet on each side of the rows of trees or shrubs. The area between the rows can be planted to an annual cover crop (e.g., grain/forage sorghum, oats, corn, millet, wheat, rye, or sunflowers) which can help control weeds, provide wildlife cover, and protect young tree seedlings from soil or wind abrasion.

Supplemental irrigation: Irrigation (e.g., hand, drip, sprinkler, furrow or flood) is not a substitute for good site preparation and weed/grass control. Irrigation should be used when soil moisture conditions are extremely dry at planting time or during a prolonged drought after planting.

Replanting: Replant all trees and shrubs that have failed in order to fill in the gaps in the windbreak. Replant annually for at least three years after the initial planting and continue until a full stand of trees is attained.

Animal protection: Establish appropriate fencing to prevent livestock and large mammal damage. Controlling small mammals can include repellents, traps, special fencing, and seedling protectors (e.g. plastic tubing or mesh netting). Consult with local and state game/wildlife specialists for control measures for your area.

Pest control: Periodic inspection of the crops and trees is recommended to detect and identify possible pests. These inspections and in some cases the use of pheromone traps will help determine when corrective action is warranted.

Pruning: Hail, wind or snow storms often cause breakage of limbs and sometimes the main trunk(s) of the trees and shrubs. Remove broken limbs and tops.

Fertilization: Generally, fertilization of windbreaks is not recommended. It is not practical, economical, or feasible, in most cases. The only situation where fertilization may be justified would be a small, high-valued windbreak planted on soils that have obvious soil nutrient deficiencies. Apply fertilizer according to soil test results.

Summary

Windbreaks protect crops, soil, and livestock while also improving air and water quality, broadening biodiversity, and beautifying the landscape. One of the keys to the successful windbreak is recognizing what the land steward wants to accomplish through its application on the landscape. The next step is to then understand the properties of a successful windbreak. And finally, choose species to plant in the windbreak that will enable it to work as expected. With a little planning upfront, a windbreak can provide a variety of benefits from improving crop production to maintaining livestock health.

Non-Agroforestry Uses of Windbreaks

1) Windbreaks for homes

Windbreaks reduce energy consumption by reducing air infiltration into buildings resulting in less heat loss and by reducing the amount of snow removal from roads and around buildings.

Windbreak Design To Protect Homes and Outbuildings

When utilizing windbreaks to protect structures such as the farmstead, roads, and other buildings, position the windbreak as close to perpendicular to the most troublesome wind direction. "One-leg" windbreaks are sufficient if winds come from one direction only, but a "two-leg" or network of windbreak(s) provides greater protection for variable wind directions.

Plan for 60-80 % density for maximum protection. Locate windward row 100 - 200 feet from area needing protection. In areas with variable winds, multiple-leg windbreaks provide greater protection to the field or farmstead than single-leg windbreaks.

Design tips

- *For wind protection only, the tallest row needs to be 2-5H (H = planned height of the tallest row) from the primary area needing protection.*
- *However, for wind and snow protection, the most windward row needs to be 100 to 200 feet from the windward edge of the primary protection area. The distance between the area needing protection and the windward row varies with the amount of space needed for snow storage. Once this critical distance is met, check to see if the area needing protection is still in the 2-5H zone, i.e. a house. Areas and objects more than 10H from the windbreak will receive reduced wind protection. To protect structures, the windbreak should have a density ranging from 60 to 80 percent during the period requiring maximum protection. To achieve the minimum level of this density range, plant at least three rows of trees and shrubs with at least one row being a conifer.*
- *Extend the windbreak a minimum of 100 feet past structures needing protection to accommodate wind turbulence at the end of the windbreak and end-drifts of snow.*
- *Locate access roads from 100 to 500 feet from the ends of the windbreak. If a lane must cut a windbreak, it should cut through the windbreak at an angle to prevailing winds to prevent funneling of wind and snow drifting.*



Community windbreaks

Planned community windbreaks can provide extra protection for the entire development and be an economic gain for the developer and homeowner from increased property values. Windbreaks in the rural-urban interface can also reduce potential conflicts, such as blowing dust, privacy, odors or noise between land uses. High quality windbreaks between agriculture and communities can prevent windblown soil and snow. Sediment in the yard, dust in homes and pesticide drift can be great aggravation to both rural and urban homeowners.

For more information see Working Trees for Communities.

Two designs for protecting a structure from snow:

Traditional multi-row windbreak: A basic farmstead windbreak consists of three to eight rows of both conifers and deciduous trees and shrubs. Conifers or shrubs should be located on the windward side with tall deciduous species in the center. A row of shrubs on the interior or leeward side completes the design.

Modified twin-row, high density wind- break: In areas with frequent heavy snows consider adding a row or two of shrubs 50 feet to the windward side to trip snow before it reaches the main windbreak. An auxiliary planting of shrubs on the leeward side of the windbreak can also add good emergency cover for wildlife. This can be supplemented with a food plot between the main windbreak and the auxiliary planting.

For more information see Windbreaks for Rural Living.

2) Windbreaks for living snow fences

Blowing and drifting snow jeopardizes public safety and emergency services, interrupts businesses, increases road maintenance costs and causes wildlife mortality.

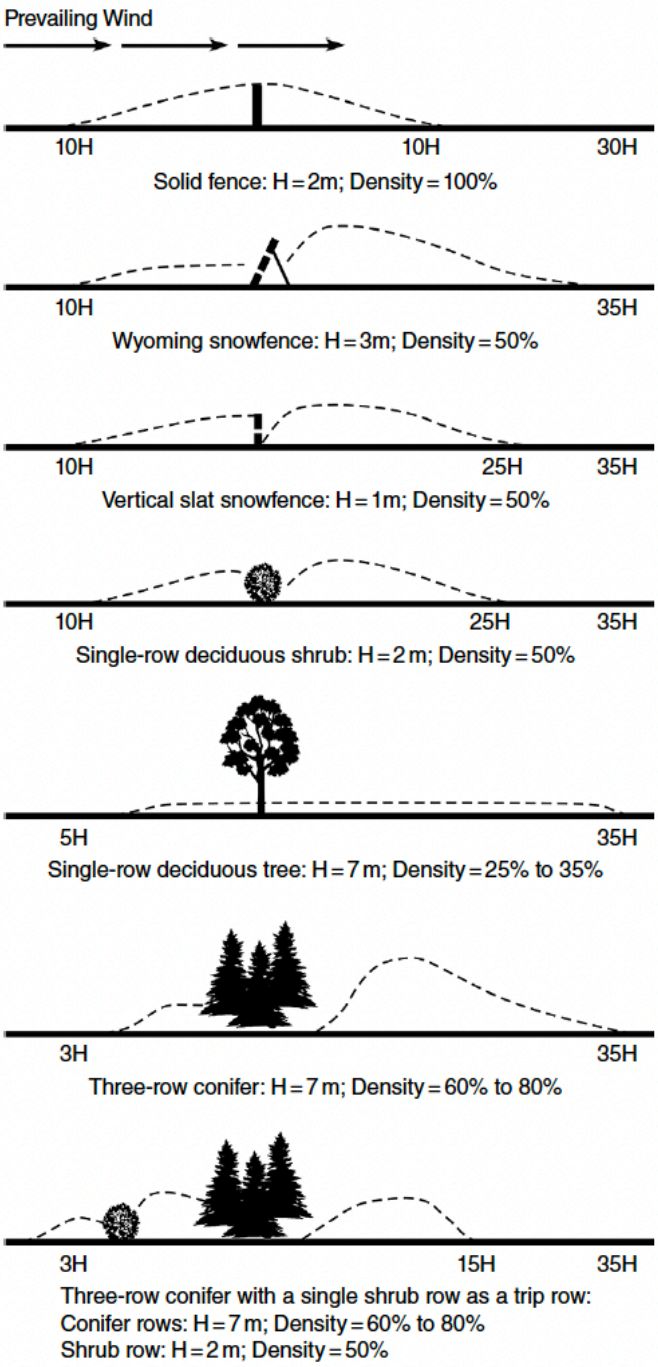


Figure 6. Windbreak designs for snow. (Brandle et al., 2021)

Living snow fences are more cost-effective than structural barriers, can meet many additional objectives, and provide a wide array of benefits beyond snow control.

Design tips

- *To achieve maximum snow accumulation, the windbreak density should range from 60 to 80 percent.*
- *The furthest windward row should be a minimum of 100 feet from the area being protected to prevent inappropriate snowdrifts. This distance will vary (100 to 300 feet) depending on the location and severity of winters.*
- *A trip row of shrubs or dense conifer can be located 50 to 100 feet windward of the main windbreak to create a snow trap.*
- *For protecting roads, allow plenty of room for the leeward drift by locating the windward row of the windbreak 200 to 300 feet from the center of the road.*

The storage capacity of a living snow fence is determined by its height and density (Fig.6).

For more information see Working Trees: Living Snow Fences and Windbreaks for Snow Management.

3) Windbreaks for livestock odor reduction

Windbreaks (or vegetative environmental buffers, VEBs) placed around livestock production facilities can help mitigate the movement of odors and dust generated by these operations. Urban expansion has placed many more people into closer contact with agricultural operations. Large scale livestock confinement production has led to increased concentrations of odor emissions traveling across highly modified landscapes relatively devoid of natural barriers. Windbreaks alone will not prevent these odor problems but can help reduce negative visual perceptions and the detection of smell by neighbors and surrounding communities.

Design tips

- *Windbreaks should consist of at least one to three rows of conifer and deciduous species.*
- *Two to three rows of trees can provide an ideal 60 percent windbreak density (or 40 percent porosity) for odor control.*
- *Shrubs are generally planted in the outside or inside rows, followed by conifers with deciduous hardwoods towards the middle or along the downwind side where they can grow more efficiently.*
- *Tree varieties and placement for the windbreak should be managed to maximize odor interception and dilution of air, and reduce odor leaving the source.*
- *Where site and facility conditions merit and allow, place plantings (not necessarily windbreaks) around*

the entire perimeter of the odor source.

- *Even a site with a windbreak on one side that is strategically placed and designed can make a difference.*

For more information see Windbreaks: A "Fresh" Tool to Mitigate Odors from Livestock Production Facilities.

4) Windbreaks for wildlife benefits

With careful design, windbreaks provide nesting habitat for a wide variety of birds (up to 57 species) and other wildlife. Windbreaks can also produce needed food as well as protective cover when the wildlife forage in adjacent areas. Shelter from predation and escape cover as well as emergency cover from severe weather.

Design tips

- ***Aesthetic appeal*** *- Windbreaks can be given a more natural look and still provide excellent wildlife habitat and wind protection.*
- ***Connecting habitats*** *- Where appropriate, select the windbreak site that connects to a larger habitat block such as a river corridor, woodlot, wetland, woody draw, or similar area.*
- ***Herbaceous cover*** *- Consider planting or leaving herbaceous vegetation such as a mixture of grasses and legumes, standing grain, or crop residues as a border (20 to 50 feet wide) along the edges of the windbreak. If grasses or legumes are used, they should be separated from the new tree planting to avoid competition. This strip of cover can provide nesting, loafing, and foraging cover for a number of species.*
- ***Winter cover*** *- Adding a shrub row 50 to 100 feet windward of the main windbreak as a snow trap results in greater wildlife protection on the leeward side of the main windbreak. Use species that will provide good thermal protection in the winter such as cedar and spruce.*
- ***Food*** *- Select species that may have high food value for a variety of wildlife. Planting food plots or fruit-bearing shrubs on the lee side of windbreaks provides food in an area protected from wind and possibly warmed by the sun, points that are particularly important in cold months.*

For more information see Windbreaks and Wildlife.

Additional Resources

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Rejuvenating an 80-year-old windbreak to enhance cattle and crop health in Kansas



At a glance: Established in 2015 at Zumbrunn Farms in Chapman, Kansas, a 640-foot, three-row windbreak featuring eastern red cedar, fragrant sumac, and common ninebark was designed to replace a deteriorating 80-year-old windbreak, providing essential protection for livestock pens on this third-generation family farm. The Zumbrunn's appreciate the benefits their livestock gain from wind protection, particularly during harsh cold weather.

Overview: Kansas is well known for its severe winds, and following the Dust Bowl era, windbreaks became a common feature across the state. These tree barriers were essential for protecting homesteads, livestock, and fields from harsh weather conditions. However, over time, many of these windbreaks deteriorated, losing their effectiveness. Lifelong farmers Cheryl and Dennis Zumbrunn recognized it was time to improve their aging 80-year-old windbreak when it no longer provided the essential wind protection needed for their livestock and homestead. Established in 1928, Zumbrunn Farms is now in its third generation. They manage 1,000 acres of cropland (wheat, soybeans, corn, and milo) and 800 acres of pasture for a 100-head cow-calf operation. Calves are backgrounded to 700-800 pounds and sold locally, while the herd winters near the farmstead and calves in the fall.

Windbreak design: When Zumbrunn Farms decided to replace their aged windbreak, they sought guidance from the Kansas State University (KSU) Forestry Department. This partnership proved invaluable, as the department not only provided a cost-effective plan but also helped secure funding through a financial assistance program. The design process began with a map outlining the planting layout, with species carefully chosen for their resilience and suitability to the local environment.

More than 300 trees and shrubs were planted with white clover seeded between the cedar rows to help with weed suppression and soil health. A row of fragrant sumac (5' spacing) was planted along the north side of the livestock pens. To enhance the old windbreak north of the house, common ninebark (4' spacing) was added to fill gaps and create a lower protective layer. Behind these, two 640' rows of eastern red cedar were planted, with 10' between trees in each row and 15' between the rows.

In addition, elderberry bushes were placed along the lane and near the west end of the cattle pen to provide initial shade. Space between the cedar and elderberry rows was used to grow pumpkins. Straw mulch, adequate rainfall, and fertile soil brought on a bumper crop. This approach offered multiple benefits: the pumpkins suppressed weeds and generated additional income through local sales, while the elderberries provided fruit and flowers for personal use (jelly, syrups, infusions). The clover further contributed by enriching the soil and supporting pollinators.

Establishment: Irrigation and weed control were essential in the early years for tree establishment. The use of poly fabric mulch around trees suppressed weeds and conserved moisture, while white clover between the rows enriched the soil and created a thriving habitat for pollinators. In the early years, maintaining the system demanded a lot of time and effort. Mowing was essential to control grass and weeds, and replanting was necessary to replace seedlings that didn't survive the tough Kansas climate. Hand weeding and occasional spot spraying for pests were also part of the routine. Over time, the need for these labor-intensive practices decreased as the trees grew strong and self-sufficient.

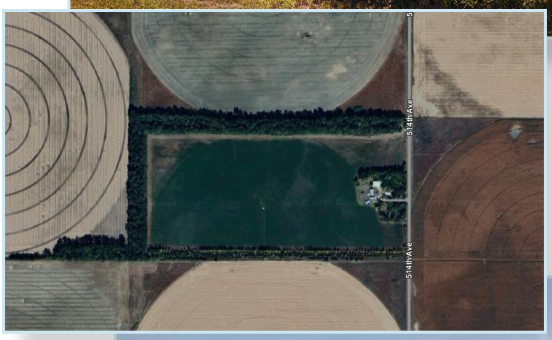
Maintenance: By the tenth year, Zumbrunn Farms transitioned to a much lower-maintenance approach. While irrigation lines and mowing were no longer required, annual pest control, particularly spraying for bagworms, remained a priority to protect the windbreak. Despite the challenges, the family looks back on the project as a rewarding endeavor, one that has transformed their landscape and provided lasting benefits for their cattle and farmstead.



Protecting organic crops with multi-age windbreaks in Nebraska



At a glance: Surrounded by miles of conventional corn-soybean row crop agriculture in Zone 5b, Sht'uh Farm stands out as a certified organic operation with 55-acres of cropland surrounded by windbreaks. Windbreaks play a crucial role in safeguarding the farm's crops, shielding them from pesticide drift and wind erosion, while also providing vital habitat for biodiversity.



Overview: Alexandra McClanahan Shively and her husband John began farming Sht'uh Farm in 2002. Already on site existed an 180' wide windbreak established in the 1930s. In their first eight years on the land, they planted rye, harvesting seed but keeping the straw in the field to improve soil quality. From 2004-2006, the couple invested in establishing a new windbreak along the farm's southern border to further enhance the resilience of their operation. These windbreaks, a combination of nearly 100-year-old historic shelterbelts and newer 20-year-old plantings, serve multiple functions. They protect the farm's organic crops from pesticide drift, reduce wind erosion, and provide critical wildlife habitat. In 2006, the couple began transitioning the farm to certified organic. After rye, Sht'uh Farm produced organic soybeans, wheat, and alfalfa. The couple has since retired and now rents farmland to a young couple who farms organically. They produce and sell alfalfa locally and use a portion for their livestock



Windbreak design: The south windbreak was planted in two phases and includes diverse species for resilience and functionality. In 2004, two rows of green ash, hackberry, and eastern red cedar were planted, spaced 14' apart with 20' between rows. Two years later, three rows of ponderosa pine and Colorado blue spruce were planted with 14' between trees and 24' between rows.

The historic windbreaks on the north and west sides of the farm provide additional protection from wind erosion and habitat for wildlife. These windbreaks are impressively wide, spanning roughly 180'. Originally planted in neat rows, they have since evolved into a thriving non-linear forest ecosystem. The trees now reseed themselves naturally, creating a self-sustaining habitat that serves as a vital refuge for wildlife. In the 1930s, commonly planted species in windbreaks included were green ash, cottonwood, box elder, mulberry, American elm, and black locust. Alexandra and John enhanced the historic windbreaks by adding a row of edible shrubs, including elderberries, plums, and sand cherries, bringing both biodiversity and multifunctionality to the landscape. They also established trails within the windbreaks, creating opportunities for easy access and exploration. These trails have the potential serve as a unique attraction if they or their renters choose to venture into agritourism in the future.

Establishment: Alexandra advises to carefully consider irrigation needs during the windbreak's early stages. Their 2004 planting coincided with a severe drought. To ensure the young trees' survival, they hand-watered each one multiple times throughout the summer using a water wagon.

The windbreaks were established with support from federal financial assistance programs and have proven to be invaluable assets for the farm. Beyond enhancing the property's value, they provide critical environmental benefits, including reducing wind erosion, creating essential wildlife habitat, and serving as buffers against pesticide drift. These functions have greatly supported Sht'uh Farm's ability to gain and maintain organic certification. However, Alexandra points out a modern challenge: the increasing use of volatile pesticides, such as dicamba, which can travel for miles under certain conditions. Despite these challenges, the windbreaks remain a vital feature of the farm, offering resilience and environmental protection in a changing agricultural landscape.

WINDBREAKS REVIEW

1. **What are the specific advantages of windbreaks for crops, soil and cattle?**
2. **How far from the windbreak will crops benefit with increased yields?**
3. **Compare and contrast the uses for single-row and multiple-row windbreaks.**
4. **When deciding between deciduous and coniferous species, what factors will also be used when writing out the management plan?**
5. **Putting in a windbreak will cause a farmer to take acres out of production. How can a farmer justify putting a windbreak?**
6. **A number of features must be analyzed prior to the placement of a windbreak. List four of these features.**

ANSWER KEY

1. Properly designed windbreaks have been shown to increase crop yield for a wide variety of crops. Decreases in wind speed protect downwind crops, decreasing evapotranspiration and increasing water use efficiency. Decreasing wind also speed enhances soil stability and is the primary basis for the installation of windbreaks dating back to the Dust Bowl of the 1930s. Cattle use energy to keep warm in the winter, increasing their feed requirement. Windbreaks moderate winter temperature extremes, reducing cold stress. Windbreaks also improve calving success rates.
2. The rule of thumb is that crop yields are improved out to 10-15H.
3. Single-row deciduous windbreaks are designed to improve snow distribution across a crop field to improve moisture for early season crop growth. They are also used surrounding orchards to still the air and improve pollination and/or speed up crop maturation. They may also be used as a visual screen along roads. Other windbreak applications depend on multiple-rows of deciduous and coniferous trees and shrubs, combined and configured for specific purposes (i.e., crop production, animal protection, snow fences).
4. Both conifers and deciduous trees bring different attributes to the function of the windbreak. Deciduous trees are more porous to wind movement and are less effective in slowing wind speeds. Conversely, deciduous windbreaks reduce wind velocity further downwind. Conifers provide much more wind blockage, critical to protect cattle, roads and buildings from wind and snow.
5. A realistic assessment of the farmers' goals and objectives, coupled with a similar assessment of the entire farm and cropping system, will lead to the diagnosis that may include establishment of windbreaks. Evidence of windblown soil erosion and associated crop damage, need for cattle protection or protection of buildings and roads, may all lead to this diagnosis. Once the diagnosis includes windbreaks, the next step is to explore financial assistance programs that may help to offset establishment costs. Visits to other land stewards that have functioning windbreaks, will be very effective in addressing farmer concerns.
6. Height, density, orientation, length, width, uniformity, cross sectional shape.