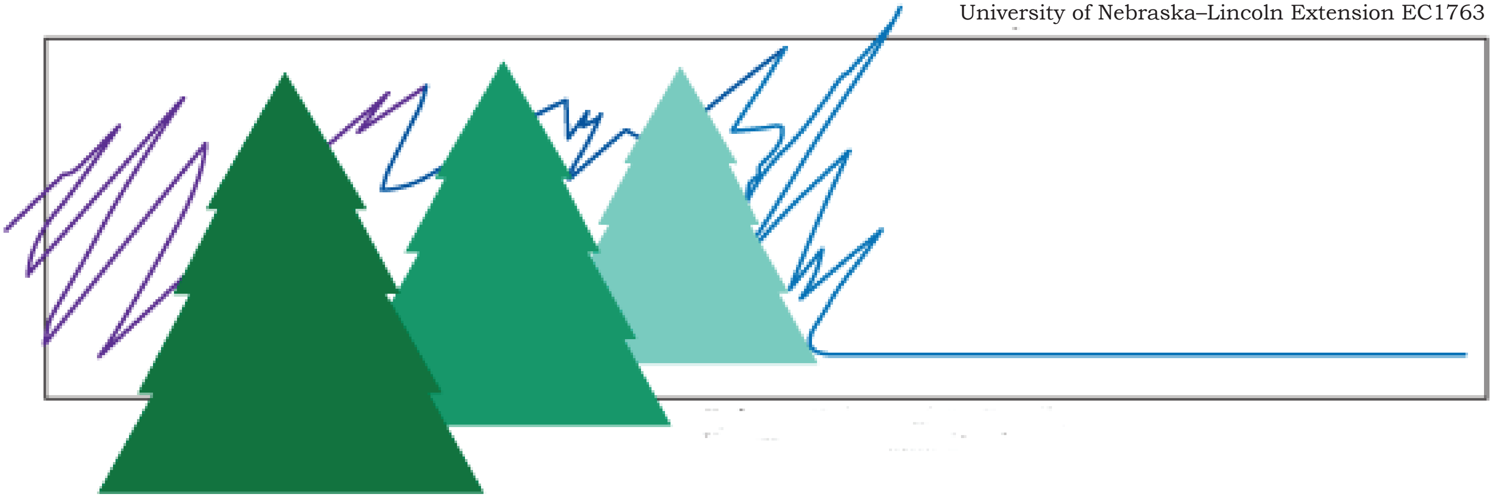

How Windbreaks Work

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EC1763 How Windbreaks Work
EC1764 Windbreak Establishment
EC1766 Windbreaks for Livestock Operations
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How Windbreaks Work

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Windbreaks are barriers used to reduce and redirect wind. They usually consist of trees and shrubs but also may be perennial or annual crops and grasses, fences, or other materials. The reduction in wind speed behind a windbreak modifies the environmental conditions or microclimate in this sheltered zone.

As wind blows against a windbreak, air pressure builds up on the windward side (the side toward the wind), and decreases on the leeward side (the side away from the wind). Some of the approaching wind flows through the windbreak, some goes around the ends, but most of it is forced up and over the top of the windbreak. Windbreak structure — height, density, number of rows, species composition, length, orientation and continuity — determines which path the wind will take, and as a result, determines how effective the windbreak will be in reducing wind speed and altering microclimate.

PFRA

A well-designed farm or ranch incorporates many types of windbreaks to protect fields, livestock, and the homesite.

Windbreak Characteristics

Effect of height, length and continuity

Windbreak **height** (H) is the most important factor determining the distance downwind protected by a windbreak. This value varies from windbreak to windbreak and increases as the windbreak matures. In multiple row windbreaks, the average height of the tallest tree row determines the value of H. Although the height of a windbreak determines the extent of the protected areas, the **length** times the extent determines the total area receiving protection. For maximum efficiency, the uninterrupted length of the windbreak should be at least 10 times its height.

The **continuity** of a windbreak also influences its efficiency. Gaps in a windbreak become funnels that accelerate wind flow, creating areas on the downwind side of the gap in which wind speeds often exceed open field wind speeds. Where gaps occur, the effectiveness of the windbreak is diminished. Lanes or field access should be located at the end of a windbreak. If a lane must go through a windbreak, it should be located such that the opening is at an angle to problem winds (*Figure 1*).

On the windward side of a windbreak, wind speed reductions are measurable upwind for a distance of two to five times the height of the windbreak (2H to 5H). On the leeward side, wind speed reductions occur up to 30H downwind of the barrier. For example, in a windbreak where the height of the tallest tree row is 30 feet, lower wind speeds are measurable for 60 to 150 feet on the windward side and up to 900 feet on the leeward side. The magnitude of the wind reduction at any location in the protected zone is determined by the structure of the windbreak.

Effect of windbreak structure

Windbreak structure is made up of two components: **internal structure** — the amount and arrangement of the solid elements and open spaces; and **external structure** — the cross-sectional shape of the windbreak.

The **internal structural** characteristics of a windbreak, especially the amount and arrangement of the surface area and volume of the trunk, branches, and leaves or needles, determine the magnitude of wind speed reductions. In practice, this internal structure is simply described in terms of density.

Windbreak **density** is the ratio of the solid portion of the barrier to the total area of the barrier. As wind flows through a windbreak, the trunk, branches and leaves (the solid portion) absorb some of the momentum of the wind and wind speed is reduced. In addition, as wind flows over the tree surfaces, it is slowed by the roughness of the surface and wind speed is reduced. Together, these two processes help determine the amount of wind speed reduction that occurs.

Around very dense windbreaks, air pressure builds up on the windward side and a zone of low pressure develops on the leeward side. The windward air pressure pushes air through and over the windbreak, while the leeward low pressure area behind the windbreak pulls air coming over the windbreak downward, creating turbulence and reducing protection downwind. As density decreases, the amount of air passing through the windbreak increases, moderating the pressure differences between the windward and leeward sides and reducing the level of turbulence created by the dense windbreak. As a result, the extent of the downwind-protected area increases. While the extent of this protected area is larger, the wind speed reductions are not as great as those leeward of a more dense windbreak. By adjusting windbreak density, different wind flow patterns and areas of protection can be established (*Figure 2*).

The species used and their arrangement, the number of rows and the distance between rows, and the distance between trees are the main factors controlling windbreak density. Increasing the number of windbreak rows or decreasing the distance between trees increases density and provides a more solid barrier to the wind. Conifer species, such as cedar and pine, and shrubs

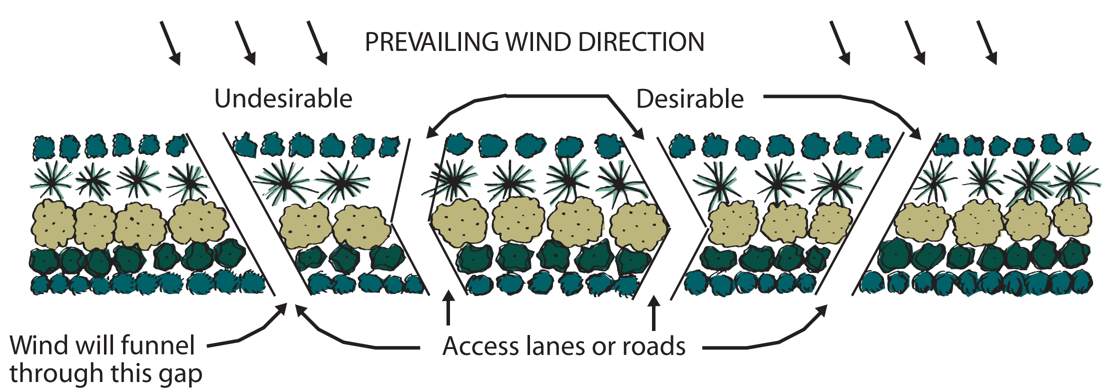

Figure 1. Acess lanes and roads should be at an angle to prevailing or troublesome winds. In areas where snow is a concern snow drifts may block lane access.

with multiple stems tend to provide better year-round density, while taller hardwood species, such as ash, oak, or hackberry, generally are used to provide greater height.

The interaction of height and density determines the degree of wind speed reduction and, ultimately, the extent of the protected area. For a windbreak with a given height, the length of the protected area downwind usually increases as density increases from 20 to 60 percent. At densities below 20 percent, the windbreak provides little, if any, useful wind reduction. As densities increase above 60 percent, leeward turbulence begins to increase, the length of the protected area downwind begins to shrink and windbreak efficiency is decreased.

The **external structure** or cross-sectional shape of a windbreak is determined by the width, height and arrangement of the individual tree and/or shrub rows within the windbreak. The cross-sectional shape of windbreaks with similar internal structures has minimal influence on wind speed reductions within 10H of the barrier. Beyond 10H, windbreaks with a vertical windward side tend to provide slightly more protection than those with a slanted windward side, because more wind passes through the barrier reducing turbulence and extending the protected area farther to the lee.

Windbreaks with a streamlined shape in cross-section, similar to a gabled roof, have been advocated in the past. This usually is achieved by planting central rows with tall trees and flanking both sides with shorter trees or shrubs. In most cases, this design is less efficient, requiring more land but not necessarily providing increased wind protection. However, these wider windbreaks provide valuable wildlife habitat benefits and are an appropriate design when wildlife habitat is an important objective of the landowner.

Windbreak design

In designing a windbreak, density should be adjusted to meet the landowner's objectives. In general, windbreaks with higher densities (multiple rows) are used to protect wildlife, farmsteads, or homesites, while windbreaks with lower densities (one or two rows) are used to protect crop fields.

A windbreak density of 40 to 60 percent provides the greatest downwind area of protection and provides excellent soil erosion control. To get uniform distribution of snow across a field, densities of 25 to 35 percent are most effective, but may not provide sufficient density to control soil erosion. Windbreaks designed to catch and store snow in a confined area usually have three to five rows of conifers or shrubs and densities in the range of 60 to 80 percent. Farmsteads and livestock areas needing protection from winter winds require multiple row windbreaks with high densities. Typically, these windbreaks have two or three rows of conifers, one or two rows of tall hardwoods, and one or more rows of shrubs. In these cases, wind speed reductions are greater but the extent of protected area is smaller.

Open Wind Speed 20 mph Deciduous 25-35% Density					
H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	10	13	16	17	20
% of open wind speed	50%	65%	80%	85%	100%
Open Wind Speed 20 mph Conifer 40-60% Density					
H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	6	10	12	15	19
% of open wind speed	30%	50%	60%	75%	95%
Open Wind Speed 20 mph Multi Row 60-80% Density					
H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	5	7	13	17	19
% of open wind speed	25%	35%	65%	85%	95%
Open Wind Speed 20 mph Solid Fence 100% Density					
H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	5	14	18	19	20
% of open wind speed	25%	70%	90%	95%	100%

Figure 2. Wind speed reductions to the lee of windbreaks with different densities. A) density of 25-35%, B) density of 40-60%, C) density of 60-80%, D) density of 100%.

Windbreaks are most effective when oriented at right angles to prevailing winds. The purpose and design of each windbreak is unique; thus, the **orientation** of individual windbreaks depends on the design objectives.

Farmsteads and feedlots usually need protection from cold winds and blowing snow or dust. Orienting these windbreaks perpendicular to the troublesome winter wind direction provides the most useful protection. This usually is accomplished by planting windbreaks on the north and west sides of the farmstead or feedlot.

Successful field windbreaks should be designed to fit within the farming operation. Consideration should be given to reducing wind erosion, providing crop protection, increasing irrigation efficiency and improving wildlife habitat.

Field crops usually need protection from hot, dry summer winds; abrasive, wind-blown soil particles; or both. The orientation of these windbreaks should be perpendicular to prevailing summer winds, usually south or west. Windbreaks designed to protect fall-seeded small grains like winter wheat may need protection from both summer and winter winds. To control soil erosion, windbreaks should be planted to block prevailing winds during the times of greatest soil exposure — usually winter and early spring. To recharge soil moisture with drifting snow, windbreaks should be placed perpendicular to prevailing winter winds.

Although wind may blow predominantly from one direction during one season, it rarely blows exclusively from that direction. As a result, protection is not equal for all areas on the leeward side of a windbreak. As the wind changes direction and is no longer blowing directly against the windbreak, the protected area decreases (*Figure 3*). The use of multiple-leg windbreaks provides a more consistent and larger protected area than a single windbreak. Again, individual placement depends on the site, wind direction(s), and design objectives.

Microclimate modifications

The reduction in wind speed adjacent to a windbreak reduces upward transport of heat and moisture from the soil surface. As a result, temperature and humidity levels in the sheltered zones usually increase and evaporation and plant water loss decrease. These changes contribute to conservation of soil moisture, improvement of crop water use efficiency and an increase in crop yields in the protected zone.

Actual temperature modifications for a given windbreak depend on windbreak height, density, orientation, and time of day. Daily air temperatures within 10H leeward of a windbreak are generally several degrees higher than temperatures in the open. Beyond 10H, air temperatures near the ground tend to be slightly cooler during the day. On most nights, temperatures near the ground in sheltered areas are slightly warmer than in the open due to the reduction in wind speed and in the upward transfer of heat from the surface. In contrast, on nights when wind speeds are very low, the reduction in wind speeds in shelter may lead to greater levels of radiation cooling and sheltered areas may be several degrees cooler than open areas. In early spring and late fall, these conditions may lead to frost in sheltered areas.

Early in the growing season, soil temperatures in sheltered areas usually are several degrees warmer than in unsheltered areas. Taking advantage of these warmer temperatures may allow earlier planting and more rapid germination in areas with short growing seasons. In the area immediately adjacent to an east-west windbreak, soil temperatures tend to be higher on the south side due to heat reflected off the windbreak. On the north side, soil temperatures, especially in the early spring, are lower due to shading by the windbreak. These cooler temperatures reduce the rate of snow melt, and, in more northern areas, may cause problems with field access in early spring.

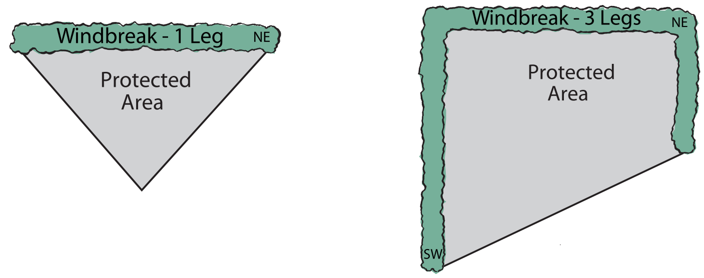

Figure 3. In areas with winds from many directions, multiple-leg windbreaks or windbreak systems provide greater protection to the field or farmstead than single-leg windbreaks.

Relative humidity in sheltered areas is two to four percent higher than in open areas. Higher humidity decreases the rate of plant water use, so production is more efficient than in unsheltered areas. However, if the windbreak is too dense and humidity levels get too high, diseases may become a problem in some crops.

Moderation of windchill is most important in farmstead and livestock windbreak situations where humans and other animals readily notice the effects of cold winter winds. Livestock use less feed and suffer less weather related stress when protected from winter winds. Similarly, good winter protection for outdoor work areas makes winter chores less stressful and reduces the risk of injury due to extreme cold.

Summary

Windbreaks reduce wind speed on both the leeward and windward sides. The resulting reductions in wind speed lead to moderation of the microclimate in these sheltered zones. With careful planning, and in consultation with local professionals, these changes in microclimate can be used to create desirable environments for growing crops, raising livestock, managing snow and protecting living and working areas. Windbreaks also provide critical wildlife habitat in a landscape dominated by agricultural crops.