USDA National Agroforestry Center
AGROFORESTRY NOTES
AF Note — 36
September 2007

Windbreak Density: Rules Of Thumb For Design

Introduction

Information on appropriate windbreak density for specific purposes is readily available. For example, living snowfences, crop protection, and snow distribution designs each have different density recommendations. However, information on selecting species and spacing to achieve a specific windbreak density is more difficult to find. Measuring or estimating windbreak density is another problem altogether. This *Agroforestry Note* provides some basic designs, including example tree species and spacing along with pictures of real windbreaks that represent the three primary ranges of density for which windbreaks are designed.

Optical density

Windbreak density is a complex subject. From an aerodynamic point of view, the three dimensional arrangement of leaves, twigs, branches, and trunks determines how the air moves through the trees and the cumulative effect they have on wind speed. From a field practitioner's point of view, it is not yet possible to design or assess the three dimensional windbreak density, but optical density can be estimated in the field. Throughout this *Agroforestry Note* the density referred to is the optical density of a windbreak. That is, when looking at the broad face of a windbreak, the proportion of the view that is filled with leaves, branches and trunk is the optical density. The portion of the view that is made up of background and sky that can be seen through the windbreak is the optical porosity. Designing a windbreak with 100 percent optical density is easily done, however greater than 80 percent three dimensional density is not achievable.

In this example the image has been altered to create higher contrast between the tree branches and the open space. The trunk, branches, twigs, and leaves, is the solid portion of the windbreak (density) and the white area is the open portion (porosity). A dot grid consisting of ten dots per inch has been laid over half of the image. By comparing the number of dots that contact the solid tree portion of the image to the number of dots that only contact white space, the density can be estimated at about 40 percent dense or 60 percent porous. Although research has determined that windbreak density is much more complicated than merely optical density, this dot grid method produces a practical estimate for evaluating and designing windbreaks. *Original photo courtesy of USDA NRCS.*

Primary density designs

Windbreak density is achieved by manipulating several factors including species, spacing, number of rows, and management activities such as pruning. Management activities and their affect on windbreak density are too broad to be discussed here. There are three major purposes of windbreaks that require distinctly different degrees of density: winter protection of structures, livestock, farmsteads, and roads as well as noise and visual screens are recommended to be greater than 60 percent dense; for crop and soil protection, 40 to 60 percent density is recommended; and for snow distribution 30 percent density is all that is needed. Very little effect on wind speed is realized with windbreaks below 30 percent density. Another factor to remember is that if the windbreak width approaches ten times the height of the windbreak (10H), the effect on wind flow changes and behaves much more like wind passing over a forest or woodlot. Under these conditions the zone of protection downwind of the windbreak is greatly reduced.

In the following examples, the species noted are suggested based on their general growth and structural characteristics. When selecting species for a specific site, choose species that are structurally similar to those suggested and are adapted to the specific site (climate, soils, etc.)

Winter protection of farmsteads, structures, or livestock; living snowfences

>60% density

Maximum wind speed reduction is desirable to protect structures and livestock from winter winds and drifting snow. The slower the wind speed the greater will be the reduction in the wind chill effect and the more snow that will be deposited into snow drifts. A windbreak consisting of only deciduous trees cannot achieve greater than 50 percent density in leaf-off condition.

Pictured left is a single row windbreak of blue spruce (*Picea pungens*) that is about 60 percent dense and 20 feet tall with six feet within row spacing.

Photo courtesy of Dr. James Brandle, University of Nebraska.

- At least two rows of conifer trees are necessary to achieve density greater than 60 percent. For example, spruces, junipers, firs and arborvitae (*Picea*, *Juniperus*, *Abies* or *Thuja* spp.) are recommended, but pines (*Pinus* spp.) tend not to be as dense and have a tendency to open up with age.
- Many shrubs, even without leaves, can provide enough density for this purpose, but only at lower heights. For example Siberian pea shrub (*Caragana* spp.) in the northern plains and "Streamco" willow (*Salix purpurea*) in the northeast have been effectively used for living snowfences to protect roads.
- Species need to be durable to withstand breakage due to the weight of accumulated snow.
- Once the basic windbreak design addresses the minimum density, additional species and rows can be added to achieve secondary goals, such as adding value for wildlife or aesthetics.

Crop protection; soil or wind erosion control

40% – 60% density

Generally speaking, 40 percent dense windbreaks provide adequate crop protection while soil erosion is better controlled by windbreaks that are 60 percent dense. Utilization of other soil erosion practices, such as managing crop residue, with 40 percent dense windbreaks can adequately protect crops and soil while avoiding problematic snow drifts that can occur with 60 percent dense windbreaks. Keep in mind that the economic benefits of crop protection windbreaks decreases as the area of the crop field planted to windbreaks increases. With many grain crops this occurs when greater than 5 percent of the crop area is planted with windbreaks.

This windbreak is composed of two rows of Scotch pine (*Pinus sylvestris*) planted at six foot spacing and about ten feet between rows. This 30 foot high windbreak is about 60 percent dense, although it obviously varies from top to bottom.

Photo courtesy of Dr. James Brandle, University of Nebraska.

- A single row of deciduous trees such as oaks, ashes, hackberry, poplars, etc. (*Quercus, Fraxinus, Celtis, Populus* spp.) planted about 12 feet apart will be about 60 percent dense and provide adequate crop protection during the growing season when the trees are in leaf.
- A single row of dense conifers, like spruces and others noted above, planted at close spacing (less than 10 feet) will be about 60 percent dense, while pine trees average about 50 percent dense.
- Two or more rows of trees increases density and reduce the possibility of gaps.
- When a shrub row is added to a tree row the density at lower heights will increase to greater than 60 percent.
- Soil erosion control and snow distribution are nearly incompatible purposes for a single windbreak. A single row of pine with wide within row spacing, 12 feet or greater, is a compromise. Another alternative is to create a system that uses 40 percent dense windbreaks with other soil conservation practices including herbaceous wind barriers and various forms of residue and tillage management.

Snow distribution

30% – 40% density

In areas where snow provides a critical source of soil moisture for crop and forage production, a windbreak can be designed to evenly distribute snow across a field. The windbreak should reduce the wind speed enough so that the wind can no longer carry all of the snow, but not so much that the wind cannot carry any of the snow resulting in a deep, narrow snow drift. Deep snow drifts, particularly in northern climates melt slowly in the spring preventing uniform surface drying of the soil and delaying field operations. However, if the windbreak density is significantly less than 30 percent, the effect on wind speed is minimal and the snow will not accumulate within the field but rather near other obstacles like fences, highways and farmsteads.

This single row of young green ash (*Fraxinus pennsylvanica*) in winter condition is about 40 percent dense and is ideal for distributing snow across a field. Potential risks of emerald ash borer suggest that species other than green ash should be used in windbreak plantings, particularly when gaps must be avoided.

Photo courtesy of USDA NRCS.

- A single row of deciduous trees such as oaks, ashes, hackberry, poplars, etc. (*Quercus*, *Fraxinus*, *Celtis*, *Populus* spp.) planted between 14 and 18 feet apart is about 40 percent dense without leaves.
- Even though snow distribution is a primary purpose, the distance between the windbreaks should be based on the crop protection or soil protection criteria, whichever is relevant for the landowner objectives and also accommodates equipment width.
- A single row of shrubs with no leaves planted at about four foot spacing is typically greater than 40 percent dense. Plantings of this density can still create drifts that are problematic in areas with high snow fall and wind. In southern areas with minimal snow fall the spring thaw occurs early enough to allow the soil to dry allowing timely field operations.

Additional information

How Windbreaks Work, Dr. James Brandle, Dr. Xinhua Zhou, Dr. Laurie Hodges; University of Nebraska Extension EC 02-1763-X

Windbreaks for Livestock Operations, Dr. Vernon Quam, Dr. LaDon Johnson, Bruce Wight; University of Nebraska Extension EC 94-1766-X

Windbreaks for Rural Living, Bruce Wight, USDA NRCS, Teresa K. Boes and Dr. James Brandle, University of Nebraska Extension EC 94-1767-X.

Windbreaks for Snow Management, Dr. James Brandle, H.Doak Nickerson; University of Nebraska Extension EC 96-1770-X

Field Windbreaks, Dr. James Brandle, Dr. Laurie Hodges; University of Nebraska Extension EC 00-1778-X

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